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ON THE THEORY OF ELECTROSTATIC GENERATORS.

BY

A. W. SIMON.

ABSTRACT.

A summary is given of the general quantitative theory of electrostatic generators in the final, simplified form, as progressively developed by the author in a number of previous papers. The method is illustrated by detailed application to (1) a four carrier, bisymmetric replenisher, (2) a six carrier, trisymmetric replenisher, (3) a four carrier, four symmetric, electrostatic alternator, and (4) a four carrier, bisymmetric, constant potential electrostatic generator. Various artifices for simplifying and shortening the labor of mathematical solution are given.

I. GENERAL THEORY.

In a number of previous papers, the author has developed a quantitative theory of the electrostatic generator. The original method, which was laborious even in application to simple machines,[1, 2, 3] was subsequently simplified and extended[4, 5] until it became capable of application even to relatively complicated machines.[6, 7, 8, 9, 10] The purpose of the present work is to give a summary of this theory in its final form, together with its principal applications, as well as to present some new material hitherto unpublished. Needless to say, the march of nuclear physics into the realm of high potentials lends new interest to this theory.

[1] A. W. Simon, *Phys. Rev.*, **24**, p. 690 (1924).
[2] A. W. Simon, *Phil. Mag.*, **49**, p. 257 (1925).
[3] A. W. Simon, *Phys. Rev.*, **25**, p. 368 (1925).
[4] A. W. Simon, *Phys. Rev.*, **26**, p. 111 (1925).
[5] A. W. Simon, *Phys. Rev.*, **28**, p. 142 (1926).
[6] A. W. Simon, *Phys. Rev.*, **27**, p. 747 (1926).
[7] A. W. Simon, *Phys. Rev.*, **28**, p. 545 (1926).
[8] A. W. Simon, *Rev. Sci. Inst.*, **1**, p. 57 (1930).
[9] A. W. Simon, *Rev. Sci. Inst.*, **4**, p. 67 (1933).
[10] A. W. Simon, *Rev. Sci. Inst.*, **4**, p. 74 (1933).

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An electrostatic generator was defined as any system of insulated conductors which is carried through a periodic cycle of electrostatic operations; where an electrostatic operation is defined as either a moving about of the conductors of the system, or a making or breaking of contact between any conductors of the system. There are, in fact, an infinite variety of these machines; those built and described historically being only a few of the possible types.

Experimentally, an electrostatic machine, in accordance with our definition, might consist of a number of smooth, spherical, copper shells of generous dimensions, in order to prevent corona and allow the system to attain relatively high potentials, mounted on pyrex or quartz pillars to prevent loss of charge by electrical leakage. In order to obviate the use of "brushes" and "combs," those conductors which move in and out of contact with others could be mounted so as to be capable of rotation about their axes, thus making rolling contact with each other as they pass. Furthermore, the entire system is operated preferably in a dry, gaseous medium at elevated pressure.

The general problem in connection with such a system is, given the initial potentials (or charges), to find the potentials and charges after a definite number n of electrostatic operations. It is not excluded that certain conductors of the system be held at constant potentials throughout the cycle; in fact a very interesting species of electrostatic generator results when this is done.[11, 12, 13] It is assumed that there is no loss of charge by electrical leakage.

The method of solution to be followed was suggested by Maxwell's theoretical treatment [14] of a very simple form of electrostatic generator, namely, the Kelvin replenisher. In order to simplify the mathematical solution, Maxwell, however, made two assumptions not generally fulfilled in practice: namely that the carriers give up all their charges to the inductors, and that, when each carrier receives its charge, it is not influenced (electrostatically) by the other inductor. A dropping of these assumptions led to a rigorous theory of the Kelvin replenisher.

The general method of solution is easily outlined. Let the position of the conductors be a function of a fundamental variable x. In the case of a rotating system, x may be actually the angle of rotation. Then if we let $Q_i(x)$ and $V_i(x)$ represent, respectively, the charge and the potential of the conductor indexed i in the position x, we have, on the basis of classical electrostatic theory:

$$Q_j(x) = \sum_{i=1}^{i=m} a_{ij}(x)\, V_i(x), \tag{1}$$

[11] A. W. Simon, *Jrl. Op. Soc.* and *Rev. Sci. Inst.*, **9**, p. 345 (1924).
[12] A. W. Simon, *Jrl. Op. Soc.* and *Rev. Sci. Inst.*, **10**, p. 669 (1925).
[13] A. W. Simon, *Phys. Rev.*, **27**, p. 341 (1926).
[14] Maxwell, "Electricity and Magnetism," **1**, p. 110, 3d Ed., 1892.

where m is the total number of conductors of the system, $a_{ii}(x)$ is the coefficient of capacity of the conductor indexed i, and $a_{ij}(x)$ is the coefficient of induction of the conductors indexed i and j, in the position x.

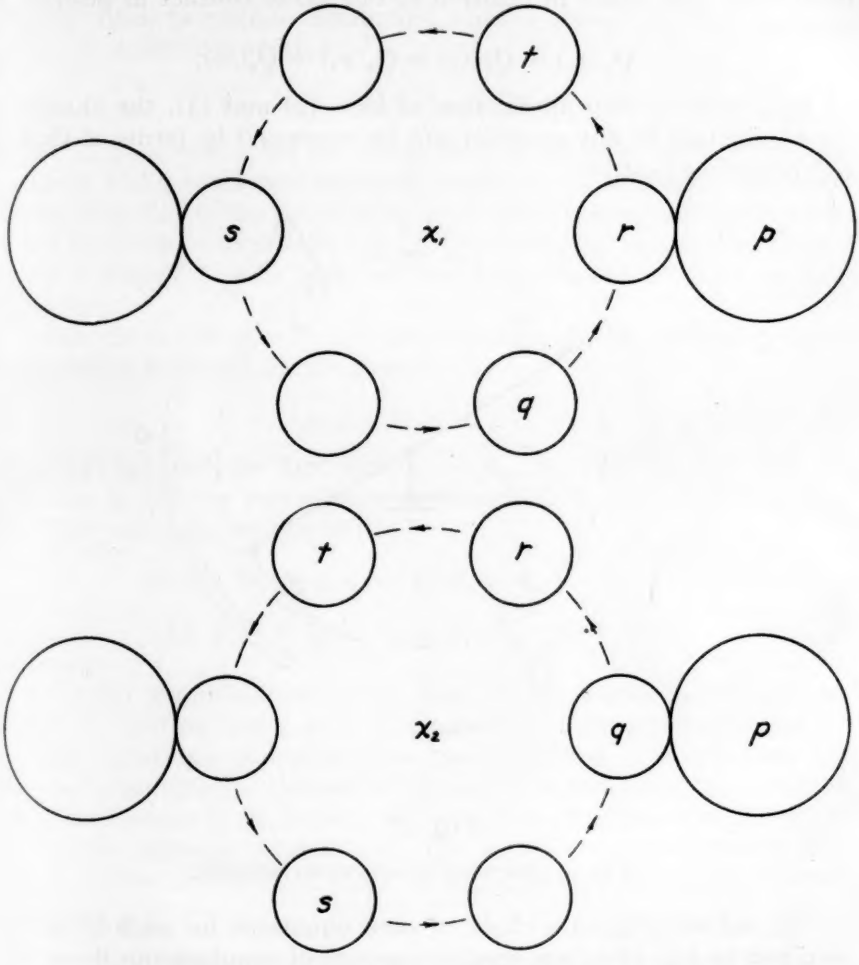

Fig. 1

FIG. 1. Theoretical diagram.

As regards the charges, for any conductor, such as that indexed t in Fig. 1, which does not make contact with other conductors of the system in its passage from the position x_1 to the position x_2, as well as for any conductor, such as either r or s of Fig. 1, which breaks contact with another conductor in position x_1 but remains insulated in its passage

from position x_1 to x_2, we can put:

$$Q_i(x_2) = Q_i(x_1), \tag{2}$$

while for any two conductors, such as p and q of Fig. 1, which are insulated from each other in position x_1 but make contact in position x_2, we have:

$$Q_p(x_2) + Q_q(x_2) = Q_p(x_1) + Q_q(x_1). \tag{3}$$

By a step-by-step application of Eqs. (2) and (3), the charges on the conductors in any position can be expressed in terms of those in any preceding position.

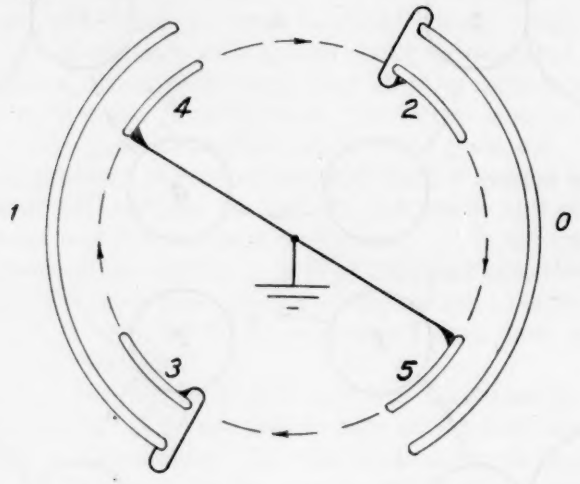

Fig. 2

FIG. 2. Bisymmetric, four carrier, replenisher.

On substituting in a chain of such equations for each Q its value as given by Eq. (1), there results a system of simultaneous linear equations, from which the potentials corresponding to any position x can be calculated in terms of the potentials at the beginning of the cycle.

However, it is readily seen that while the solution is simple in principle, it will be laborious in application on account of the number of electrostatic coefficients which must be taken into account; for example, even in the case of a relatively simple machine comprising only 6 elements, such as that of Fig. 2, 36 coefficients must be dealt with.

The solution can be greatly simplified by the use of two artifices, namely: a special notation for the electrostatic coefficients of two or

more conductors in contact; and a special matrix notation for the (algebraic) coefficients involved in the potential equations. Additional simplifications result in cases where the machine presents geometrical symmetries, as well as in cases where the electrostatic cycle is simple.

In the case where two conductors p and q are in contact, but are insulated from two other conductors r and s also in contact, it is convenient to define the symbol:

$$a_{p,\,q\cdot r,\,s} = a_{pr} + a_{ps} + a_{qr} + a_{qs}; \tag{4}$$

in fact $a_{p,\,q\cdot p,\,q}$ represents the coefficient of capacity of the two conductors p and q connected together; while $a_{p,\,q\cdot r,\,s}$ represents the coefficient of induction of the two conductors p and q connected together with respect to the two conductors r and s also connected together, as pointed out by Maxwell.[15] The notation can be extended to three or more conductors.

Furthermore, since only the subscripts are significant in Eq. (4), it is convenient to introduce the notation:

$$(p,\, q\cdot r,\, s) = a_{p,\,q\cdot r,\,s}. \tag{5}$$

From Eq. (4) and the fact that $a_{ij} = a_{ji}$, we can operate with the quantities inside the parenthesis as though they were algebraic numbers;[16] for example, we can write:

$$(p,\, q\cdot r,\, s) = (p,\, q\cdot r) + (p,\, q\cdot s), \tag{6}$$

$$(p,\, q\cdot r) = (p\cdot r) + (q\cdot r) = (r\cdot p) + (r\cdot q), \tag{7}$$

and so on.

A further simplification in the labor of the mathematical solution consists in writing down only the matrices of the coefficients of the potential equations; and even these can be written in simple form provided we note that any element of the matrix is composed of a combination of the indices of the conductors on which charges are induced with those of the inducing conductors. The method of application of these artifices will be illustrated in detail by application to several electrostatic generators.

II. THEORY OF A BISYMMETRIC, FOUR CARRIER REPLENISHER.

A relatively simple electrostatic generator, comprising only six elements, namely two inductors and four carriers, is shown schematically in Fig. 2. It is assumed that the machine is bisymmetric, and that all four brushes break simultaneously. In this case a complete electrostatic cycle is one quarter turn. In setting up the equations, the

[15] Maxwell, *loc. cit.*,[14] p. 321.

[16] The commutative, associative, and distributive laws hold for the numbers within the parenthesis.

individual conductors are not indexed but only the positions which they occupy.

If we denote by n the number of electrostatic cycles which have elapsed, we can write as the equations for the charges:

$$\begin{aligned} Q_0(n+1) + Q_2(n+1) &= Q_0(n) + Q_4(n), \\ Q_1(n+1) + Q_3(n+1) &= Q_1(n) + Q_5(n). \end{aligned} \tag{8}$$

If next we substitute for each charge its value as given by Eq. (1), we have:

$$\begin{aligned} aV_0(n+1) + bV_1(n+1) &= a'V_0(n) + b'V_1(n), \\ bV_0(n+1) + aV_1(n+1) &= b'V_0(n) + a'V_1(n), \end{aligned} \tag{9}$$

where the coefficients a, b, a', b', which are the fundamental electrostatic parameters of the machine, are given by:

$$\begin{aligned} a &= (0, 2\cdot 0, 2) = (1, 3\cdot 1, 3), \\ b &= (0, 2\cdot 1, 3) = (1, 3\cdot 0, 2), \\ a' &= (0, 2\cdot 0, 4) = (1, 3\cdot 1, 5), \\ b' &= (0, 2\cdot 1, 5) = (1, 3\cdot 0, 4). \end{aligned} \tag{10}$$

The second equalities follow from the two-fold symmetry. Written in matrix form, Eqs. (9) become simply:

	0, 2	1, 3
0, 2	a	b
1, 3	b	a

	0, 2	1, 3
0, 4	a'	b'
1, 5	b'	a'

(11)

It will be seen that the numbers at the heads of the columns are those corresponding to the inducing conductors, while the numbers at the heads of the rows are those corresponding to the conductors on which charges are induced (Eqs. (8)).

If now we form the sum and difference of the two Eqs. (9), and set therein:

$$\begin{aligned} S(n) &= V_0(n) + V_1(n), \\ D(n) &= V_0(n) - V_1(n), \end{aligned} \tag{12}$$

we have:

$$\begin{aligned} (a+b)S(n+1) &= (a'+b')S(n), \\ (a-b)D(n+1) &= (a'-b')D(n), \end{aligned} \tag{13}$$

whence:

$$\begin{aligned} S(n) &= S(0)r_0^n, \\ D(n) &= D(0)r_1^n, \end{aligned} \tag{14}$$

where:

$$\begin{aligned} r_0 &= (a'+b')/(a+b), \\ r_1 &= (a'-b')/(a-b). \end{aligned} \tag{15}$$

Forming, in turn, the sum and difference of Eqs. (14), we have as the solution of Eqs. (9):

$$\begin{aligned} 2V_0(n) &= [V_0(0) + V_1(0)]r_0^n + [V_0(0) - V_1(0)]r_1^n, \\ 2V_1(n) &= [V_0(0) + V_1(0)]r_0^n - [V_0(0) - V_1(0)]r_1^n. \end{aligned} \tag{16}$$

Eqs. (16) give the potentials of the inductors after any integral number n of quarter turns, in the position in which the carriers just break contact with the brushes.

By virtue of Eqs. (15) and (10), the quantities r_0 and r_1 appearing in Eqs. (14) and (16) are functions only of the electrostatic coefficients of the machine in the position where the carriers just break contact with the brushes; and it is seen from the same equations that dimensionally these quantities are ratios or pure numbers. In fact, as can be seen from Eqs. (16), they represent the factors by which, under certain initial conditions, the potentials of the inductors increase or decrease, depending on the numerical value of r_0 and r_1, per quarter turn. It becomes of interest, therefore, to investigate the possible range of values of these quantities.

Selecting first r_0 for analysis, from Eqs. (15) and (10), it follows that r_0 can be written in the form:

$$r_0 = (1 + f_1)/(1 + f_2), \tag{17}$$

where f_1 and f_2 are given by:

$$\begin{aligned} f_1 &= (0, 2\cdot4, 5)/(0, 2\cdot0, 1), \\ f_2 &= (0, 2\cdot2, 3)/(0, 2\cdot0, 1), \end{aligned} \tag{18}$$

but from the properties of electrostatic coefficients, we must have:

$$(0, 2\cdot4, 5) < 0, \tag{19}$$

$$(0, 2\cdot0, 1) = (0\cdot0, 1, 2, 3) > 0, \tag{20}$$

$$(0, 2\cdot2, 3) = (2\cdot0, 1, 2, 3) > 0, \tag{21}$$

so that $f_1 < 0$, while $f_2 > 0$; whence $r_0 < 1$, under *all* conditions. Furthermore, it can be shown that under *ordinary* conditions r_0 will be positive. Since f_2 is positive, in order that r_0 be positive, we must have:

$$(1 + f_1) > 0, \tag{22}$$

that is:

$$(0, 2\cdot0, 1) + (0, 2\cdot4, 5) > 0, \tag{23}$$

but the last inequality can be written in the form:

$$(0\cdot0) + (0\cdot1, 2, 3, 4, 5) + (2\cdot4, 5) > 0, \tag{24}$$

a condition which will be fulfilled ordinarily, for the coefficient of capacity, namely $(0\cdot0)$, of the inductor will be large in comparison with the other coefficients, since the inductors will ordinarily be much larger

than the carriers; moreover, the condition of Eq. (24) will definitely be assured if Leyden jars are connected to the inductors, as will usually be the case. Hence we can conclude that in practice:

$$0 < r_0 < 1. \tag{25}$$

Turning next to r_1, we note that r_1 can be written in the form:

$$r_1 = (1 + f_3)/(1 + f_4), \tag{26}$$

where f_3 and f_4 are given by:

$$f_3 = [(0, 2\cdot 4) - (0, 2\cdot 5)]/[(0, 2\cdot 0) - (0, 2\cdot 1)], \tag{27}$$

$$f_4 = [(0, 2\cdot 2) - (0, 2\cdot 3)]/[(0, 2\cdot 0) - (0, 2\cdot 1)], \tag{28}$$

but from the properties of electrostatic coefficients, we have:

$$(0, 2\cdot 0) - (0, 2\cdot 1) > 0, \tag{29}$$

$$(0, 2\cdot 2) - (0, 2\cdot 3) > 0, \tag{30}$$

so that f_4 is positive under all conditions. For $r_1 \geqq 2$, we would therefore require:

$$(f_3 - 1) \geqq 2f_4, \tag{31}$$

that is:

$$(0, 2\cdot 1, 3, 4) + (0, 2\cdot 3) - (0, 2\cdot 0, 2, 5) - (0, 2\cdot 2) \geqq 0. \tag{32}$$

However, from the properties of electrostatic coefficients, this is impossible. Hence, under all conditions, $r_1 < 2$.

Parenthetically, it might be noted that the fact that $r_1 < 2$ under all conditions can be deduced also from physical considerations. In particular, since the charge induced on the grounded carrier can at most equal the charge on the system comprising the inductor and the contacting carrier, the charge on the latter system can at most double per quarter turn, that is, we must have $r_1 < 2$. This can be proved formally from Eqs. (8) by noting that we must have:

$$Q_4(n) < Q_0(n) + Q_2(n).$$

By shifting the brushes in the direction of rotation, a position could be found for which $f_3 = f_4$, that is $r_1 = 1$. In particular, this would occur when:

$$(0, 2\cdot 3, 4) = (0, 2\cdot 2, 5). \tag{33}$$

The last equation can also be deduced from the fact that for this condition we would require:

$$Q_4(n) = Q_2(n), \qquad V_0(n) = -V_1(n).$$

Further shifting of the brushes in the same direction would cause r_1 to decrease towards zero.

For $r_1 < 0$, we would require $1 + f_3 < 0$, that is:

$$(0, 2 \cdot 0, 4) - (0, 2 \cdot 1, 5) < 0, \tag{34}$$

which can also be written:

$$(0 \cdot 0, 2, 4) - (0, 2 \cdot 1, 5) < -(2 \cdot 4), \tag{35}$$

a condition which cannot be fulfilled in practice since the magnitude of $(2 \cdot 4)$ will be small in comparison with the magnitude of the entire left member. Hence we can conclude that in practice:

$$0 < r_1 < 2. \tag{36}$$

It is of interest to examine the value of r_1 for the condition that $(0 \cdot 0)$ is large in comparison with the other coefficients, which would be the case, for example, when Leyden jars are connected to the inductors. Under these conditions r_1 would be given approximately by:

$$r_1 = 1 + c/C, \tag{37}$$

where c is the numerical value of the coefficient of induction $(0 \cdot 5)$ and C is the capacity of the inductor and associated structures (Leyden jars).

With the help of these results we can predict the behavior of the machine of Fig. 2.

(1) If the potentials of the inductors are originally equal in magnitude and the same in sign, they will decrease by a constant factor each quarter turn, that is to say, the action of the machine will be merely to discharge the inductors.

(2) If the potentials of the inductors are originally equal in magnitude but opposite in sign, they will increase by a constant factor each quarter turn, and increase without limit as the machine continues to rotate.

(3) If the potentials of the inductors are originally unequal, they will tend to approach a state in which they are equal in magnitude but opposite in sign, and then increase without limit as the machine continues to rotate. The term in r_0, therefore, has the significance of a transient term, which is damped out, or is absent altogether if the initial potentials are in proper phase relation.

An important result of the analysis is that theoretically the potentials of the inductors increase without limit as the machine continues to rotate; the machine can therefore be used to attain any desired potential. In practice this means that the attainable voltages are limited only by the breakdown of the insulation, and by proper design can be made as high as desired.

III. THEORY OF THE TRISYMMETRIC REPLENISHER.

The machine of Fig. 2 may be considered as the two symmetric member of a whole family of polysymmetric static machines, in which

the number of symmetries can be both even and odd.[17] The trisymmetric member of this family is shown in Fig. 3. However, while the latter is a member of the same family as the bisymmetric machine of Fig. 2, its electrical behavior is, superficially at least, very different from the other; hence its theory will be given in detail, and furthermore in a form which permits of ready generalization to a machine of this type with any number of symmetries.

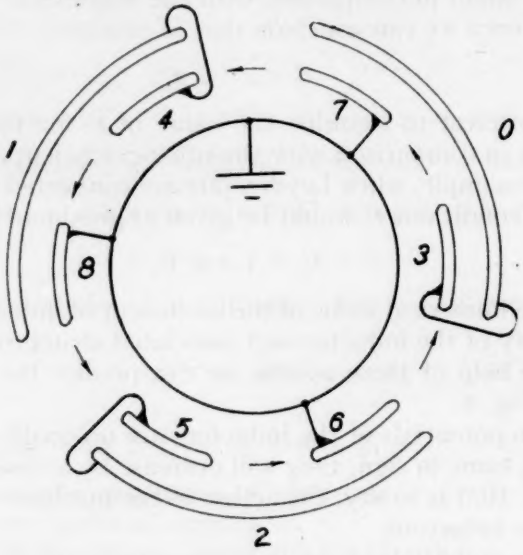

Fig. 3

FIG. 3. Trisymmetric replenisher.

With the scheme of indexing of Fig. 3, the equations for the charges become:

$$\begin{aligned} Q_0(n+1) + Q_3(n+1) &= Q_0(n) + Q_6(n), \\ Q_1(n+1) + Q_4(n+1) &= Q_1(n) + Q_7(n), \\ Q_2(n+1) + Q_5(n+1) &= Q_2(n) + Q_8(n), \end{aligned} \tag{40}$$

where $n(=0, 1, 2, 3, \cdots)$ now represents the number of one-sixth revolutions through which the rotor of the machine has turned. On elimination of the Q's, there results a set of three equations of which the left members take the form:

$$\begin{aligned} &a_0V_0(n+1) + a_2V_1(n+1) + a_1V_2(n+1), \\ &a_1V_0(n+1) + a_0V_1(n+1) + a_2V_2(n+1), \\ &a_2V_0(n+1) + a_1V_1(n+1) + a_0V_2(n+1), \end{aligned} \tag{41}$$

[17] A. W. Simon, *loc. cit.*[8]

and the right members take the same form except that every a_i is replaced by an a_i' and the argument $(n + 1)$ by n. The a's, which are the fundamental electrostatic parameters of the machine, are given by:

$$\begin{aligned} a_0 &= (0, 3\cdot 0, 3) & a_0' &= (0, 3\cdot 0, 6), \\ a_1 &= (0, 3\cdot 1, 4) & a_1' &= (0, 3\cdot 1, 7), \\ a_2 &= (0, 3\cdot 2, 5) & a_2' &= (0, 3\cdot 2, 8). \end{aligned} \tag{42}$$

In order to solve Eqs. (41) we make use of the following matrix:

$$\begin{bmatrix} \omega_0^0 & \omega_0^1 & \omega_0^2 \\ \omega_1^0 & \omega_1^1 & \omega_1^2 \\ \omega_2^0 & \omega_2^1 & \omega_2^2 \end{bmatrix} \tag{43}$$

where ω_j represents the cube root of unity of amplitude $j(2\pi/3)$, where $j = 0, 1, 2$. In what follows the rows and columns of the matrix will be numbered from 0 onward.

If now we multiply Eqs. (41) by the elements in the jth column of the matrix (43) and add, we obtain an equation of the form:

$$A_j S_j(n + 1) = A_j' S_j(n), \tag{44}$$

where A, A' and S are given by:

$$A_j = a_0\omega_0^j + a_1\omega_1^j + a_2\omega_2^j, \tag{45}$$

$$A_j' = a_0'\omega_0^j + a_1'\omega_1^j + a_2'\omega_2^j, \tag{46}$$

$$S_j(n) = \omega_0^j V_0(n) + \omega_1^j V_1(n) + \omega_2^j V_2(n), \qquad j = 0, 1, 2. \tag{47}$$

The solution of Eq. (44) is obviously:

$$S_j(n) = r_j^n S_j(0), \tag{48}$$

where

$$r_j = (A_j'/A_j). \tag{49}$$

In order to recover the V's, we set successively j equal to 0, 1, 2, in Eq. (48), and replace every ω_p^q by its equivalent ω_q^p, whence we have:

$$\begin{aligned} \omega_0^0 V_0(n) + \omega_0^1 V_1(n) + \omega_0^2 V_2(n) &= S_0(0) r_0^n, \\ \omega_1^0 V_0(n) + \omega_1^1 V_1(n) + \omega_1^2 V_2(n) &= S_1(0) r_1^n, \\ \omega_2^0 V_0(n) + \omega_2^1 V_1(n) + \omega_2^2 V_2(n) &= S_2(0) r_2^n, \end{aligned} \tag{50}$$

the matrix of the coefficients of the left members of Eq. (50) being again the matrix (43). Now the latter has two properties which allow the V's to be recovered very easily.

(1) The sum of the elements in any column of the matrix is the sum of like powers of the roots of the algebraic equation $x^3 - 1 = 0$, and, therefore, from the theory of equations, the sum of the elements in every column of the matrix (or row, if we replace every element of the form ω_p^q by ω_q^p) except the first is zero.

(2) If each row is divided through by the factor which will make the elements in the sth column all unity, the resulting matrix can be obtained by s cyclic permutations of the columns of the original matrix, and therefore has the property that the sum of the elements in every column except the sth is zero.

Applying these principles to Eqs. (48), we have immediately:

$$3V_s(n) = \sum_{j=0}^{j=2} r_j{}^n S_j(0)/\omega_{sj}, \tag{51}$$

where s ($= 0, 1, 2$) represents the index number of the inductor whose potential is desired, and ω_{sj} represents the cube root of unity whose amplitude is $sj(2\pi/3)$. The last equation is the general solution of Eq. (41).

From Eq. (47) it is seen that the general solution takes simple forms provided the original potentials ($n = 0$) are in proper phase relation. In particular, if we have:

$$\omega_p{}^2 V_0(0) = \omega_p{}^1 V_1(0) = \omega_p{}^0 V_2(0), \qquad p = 0, 1, 2, \tag{52}$$

$$S_j(0) = (\omega_0{}^{(j+p)} + \omega_1{}^{(j+p)} + \omega_2{}^{(j+p)}) V_0(0), \tag{53}$$

so that $S_j(0) = 3V_0(0)$ or 0, according as $(j + p)$ is or is not, 0 or a multiple of 3. Accordingly, we can distinguish three cases:

Case (1) $p = 0$; $V_0(0) = V_1(0) = V_2(0)$; that is, the original potentials of the inductors are all equal. In this case we have:

$$V_s(n) = V_0(0) r_0{}^n. \tag{54}$$

Case (2) $p = 1$; $V_0(0) = V_1(0) \cos \delta = V_2(0) \cos 2\delta$; that is, the original potentials differ by a phase angle of $\delta = 2\pi/3$. In this case we have:

$$V_s(n) = V_0(0) \rho^n \cos (n\theta - s\delta), \tag{55}$$

where we have put:

$$r_1 = \rho(\cos \theta + i \sin \theta). \tag{56}$$

Case (3) $p = 2$; that is, the original potentials differ by a phase angle of $2\delta = 4\pi/3$. This is equivalent to case (2). This is in fact the conjugate imaginary of case (2), for we have:

$$r_2 = \rho(\cos \theta - i \sin \theta). \tag{57}$$

In order to describe completely the action of the machine of Fig. 3, we require the range of values of r_0, ρ, and θ.

With regard to the first of these, by a method exactly paralleled to that employed in the case of the bisymmetric machine, it can be shown that:

$$0 < r_0 < 1. \tag{58}$$

The latter can be deduced also from qualitative considerations. In particular $p = 0$ corresponds to the case, as already pointed out, where the original potentials of the inductors are all equal; under these conditions the sign of the charge induced on each of the grounded carriers is such as to neutralize subsequently a portion of the charge of the next inductor, so that the charges and, therefore, the potentials, of the inductors must eventually be reduced to zero, that is, r_0 must be less than unity.

The quantities ρ and θ, on the other hand, require a separate analysis. In order to evaluate these quantities it is convenient to set:

$$r_1 = A_1'/A_1 = \rho(\cos\theta + i\sin\theta), \tag{59}$$

$$A_1' = \sigma'(\cos\phi' + i\sin\phi') = \alpha' + i\beta', \tag{60}$$

$$A_1 = \sigma(\cos\phi + i\sin\phi) = (\alpha + i\beta), \tag{61}$$

whence we have:

$$\rho = \sigma'/\sigma, \qquad \theta = \phi' - \phi, \tag{62), (63}$$

$$\tan\phi' = \beta'/\alpha', \qquad \tan\phi = \beta/\alpha. \tag{64), (65}$$

A comparison of Eqs. (60) and (61) with Eqs. (45) and (46), together with a consideration of the fact that ω_j is given by the equation:

$$\omega_j = \cos j(2\pi/3) + i\sin j(2\pi/3), \tag{66}$$

yields further:

$$2\alpha' = 2a_0' - (a_1' + a_2'), \tag{67}$$

$$2\beta' = \sqrt{3}(a_1' - a_2'), \tag{68}$$

$$\alpha = (a_0 - a_1), \tag{69}$$

$$\beta = (a_1 - a_2). \tag{70}$$

Selecting now $\tan\phi$ for further analysis, we have, in view of the fact that $a_1 = a_2$, that is, $\beta = 0$:

$$\tan\phi = \phi = 0. \tag{71}$$

Selecting next $\tan\phi'$ for further analysis, we note that the latter can be written in the form:

$$\tan\phi' = N/\sqrt{3}D = C/\sqrt{3}, \tag{72}$$

where

$$N = 3(a_1' - a_2'), \tag{73}$$

$$D = 2a_0' - (a_1' + a_2'). \tag{74}$$

By methods similar to those employed in the case of the bisymmetric machine, it can be shown that in practice:

$$-1 < C < 0, \tag{75}$$

whence

$$0 < \phi' < \pi/6, \tag{76}$$

and, in view of Eq. (63), therefore also:

$$0 < \theta < \pi/6. \tag{77}$$

Selecting lastly ρ for analysis, we have, since $\beta = 0$:

$$\rho = [(\alpha'/\alpha)^2 + (\beta'/\alpha)^2]^{\frac{1}{2}}. \tag{78}$$

With regard to the ratios under the radical sign, it can be shown that in practice: $-\frac{\sqrt{3}}{2} < (\beta'/\alpha) < 0$,

$$0 < (\alpha'/\alpha) < 3/2, \tag{79}$$

whence:

$$0 < \rho < \sqrt{3}. \tag{80}$$

With these results we can predict the behavior of the trisymmetric replenisher of Fig. 3.

(1) If the potentials of the inductors are originally equal in magnitude and the same in sign, they will decrease by a constant factor each one-sixth turn, that is to say, the action of the machine is merely to discharge the inductors.

(2) If the potentials of the inductors are originally 120° out of phase, they will remain in this relation, but the potential of any inductor will alternate and at the same time increase in value, and increase indefinitely as the machine continues to rotate. Under these conditions the machine becomes essentially an electrostatic alternator. The period of alternation will depend on the capacities involved in the machine but will approach the time of 2 revolutions as a lower limit.

(3) If the original potentials satisfy neither of these conditions, they will continually tend toward a state in which they are 120° out of phase and then behave as in (2). Experimentally the state (2) is attained very rapidly, even for the condition (1), because in practice it is difficult to maintain perfect equality of potential between conductors, on account of ever present contact e.m.f.'s, etc., and the slightest unbalance is rapidly multiplied.

Again it is important to note that theoretically also for the machine of Fig. 3 there is no limit to the attainable potential. This means that in practice the attainable voltage is limited only by breakdown of the insulation and by proper design can be made as large as desired.

IV. THEORY OF A FOUR SYMMETRIC ELECTROSTATIC ALTERNATOR.

A remarkably simple form of electrostatic alternator,[18] in particular the four symmetric member of a whole family of polysymmetric electrostatic alternators, is shown in Fig. 4. We shall present the theory of

[18] A. W. Simon, *loc. cit.*[3]

this machine in terms of the method of treatment and notation as finally developed.

The equations for the charges are:

$$\begin{aligned} Q_0(n+1) + Q_4(n+1) &= Q_0(n) + Q_7(n), \\ Q_1(n+1) + Q_5(n+1) &= Q_1(n) + Q_4(n), \\ Q_2(n+1) + Q_6(n+1) &= Q_2(n) + Q_5(n), \\ Q_3(n+1) + Q_7(n+1) &= Q_3(n) + Q_6(n). \end{aligned} \tag{81}$$

The matrix of the coefficients of the left members of the potential

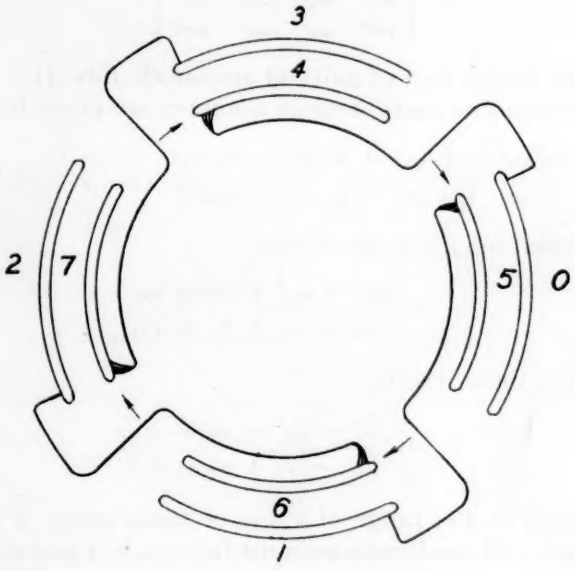

Fig. 4

FIG. 4. Four symmetric electrostatic alternator.

equations take the form:

$$\begin{bmatrix} a_0 & a_3 & a_2 & a_1 \\ a_1 & a_0 & a_3 & a_2 \\ a_2 & a_1 & a_0 & a_3 \\ a_3 & a_2 & a_1 & a_0 \end{bmatrix} \tag{82}$$

and of the right members exactly the same form except that every a_i is replaced by an a_i'. The matrix (82) is a cyclic matrix of the fourth order; and it can be stated that in general the matrix of the coefficients of the potential equations of an alternator of this type of p symmetries would be a cyclic matrix of the pth order. The fundamental electro-

static parameters of the machine of Fig. 4 are given by:

$$\begin{aligned} a_0 &= (0, 4\cdot0, 4), & a_0' &= (0, 4\cdot0, 7), \\ a_1 &= (0, 4\cdot1, 5), & a_1' &= (0, 4\cdot1, 4), \\ a_2 &= (0, 4\cdot2, 6), & a_2' &= (0, 4\cdot2, 5), \\ a_3 &= (0, 4\cdot3, 7), & a_3' &= (0, 4\cdot3, 6). \end{aligned} \tag{83}$$

The fundamental matrix employed in the solution is:

$$\begin{bmatrix} \omega_0^0 & \omega_0^1 & \omega_0^2 & \omega_0^3 \\ \omega_1^0 & \omega_1^1 & \omega_1^2 & \omega_1^3 \\ \omega_2^0 & \omega_2^1 & \omega_2^2 & \omega_2^3 \\ \omega_3^0 & \omega_3^1 & \omega_3^2 & \omega_3^3 \end{bmatrix} \tag{84}$$

where ω_j is the fourth root of unity of amplitude $j(2\pi/4)$.

The corresponding roots (four in number) are given by:

$$r_j = \frac{(a_0'\omega_0^j + a_1'\omega_1^j + a_2'\omega_2^j + a_3'\omega_3^j)}{(a_0\omega_0^j + a_1\omega_1^j + a_2\omega_2^j + a_3\omega_3^j)}, \qquad j = 0, 1, 2, 3. \tag{85}$$

In particular, for $j = 0$ we obtain:

$$r_0 = \frac{(a_0' + a_1' + a_2' + a_3')}{(a_0 + a_1 + a_2 + a_3)}, \tag{86}$$

while for $j = 2$ these results:

$$r_2 = \frac{(a_0' - a_1' + a_2' - a_3')}{(a_0 - a_1 + a_2 - a_3)}. \tag{87}$$

With regard to the range of value of these roots, it is possible to show that under all conditions we must have $r_0 = 1$ and $r_2 < 1$. These two roots are, moreover, the roots corresponding, respectively, to the relatively trivial conditions (1) where the initial potentials are all equal, in which case no change takes place, as might be expected also from qualitative considerations; and (2) where they are alternately equal and opposite, in which case the action of the machine is merely to discharge the inductors.

If, however, the original potentials lag each other by an angle of 90°, we have as the solution of the potential equations:

$$V_s(n) = V_0(0)\rho^n \cos(n\theta - s\delta), \tag{88}$$

where $\delta = 2\pi/4$ and $s = 0, 1, 2, 3$. The corresponding root is obtained by setting $j = 1$ or 3 in Eq. (85). Further investigation shows that the maximum value of ρ is $\sqrt{2}$, and that the period of alternation approaches the time of 2 revolutions as a lower limit ($\theta < \pi/4$). Hence we can conclude that the machine of Fig. 4 is inherently an electrostatic alternator, and experimentally this is indeed found to be the case.

An eight symmetric alternator of this type has been studied in detail.[19]

V. THEORY OF CONSTANT POTENTIAL ELECTROSTATIC GENERATORS.

The machines so far discussed have the disadvantage that on continued rotation the potentials build up until electrical breakdown occurs. Of course, it is possible to conceive of schemes whereby this disadvantage could be overcome: theoretically, for example, the rotor

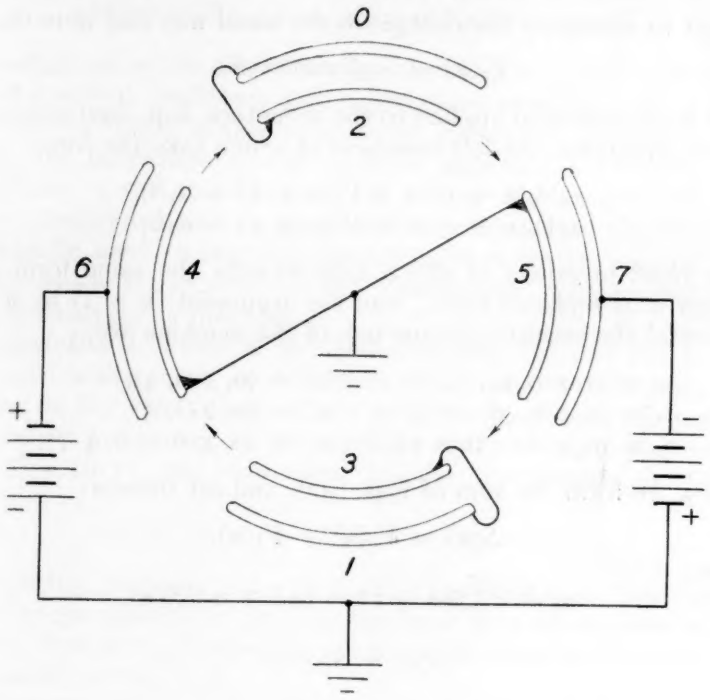

Fig. 5

FIG. 5. Constant potential electrostatic generator.

could be stopped when the desired potential had been attained, or the brushes could be shifted to a neutral position. However, there is a class of electrostatic generators which are inherently constant potential machines, and we shall consider next the theory of a simple machine [20] of this type.

The particular machine studied is shown in Fig. 5, from which its mode of action can be seen readily. It differs from the machines

[19] A. W. Simon, *loc. cit.*[5]
[20] A. W. Simon, *loc. cit.*[13]

previously treated in that it is separately excited, that is to say, while the conductors of the system are carried through their cycle of electrostatic operations, some of them, namely the inductors, are held at constant potential by an external source of electromotive force, such as a battery, D.C. generator, etc.

If we write the equations for the charges, we have:

$$\begin{aligned} Q_0(n+1) + Q_2(n+1) &= Q_0(n) + Q_4(n), \\ Q_1(n+1) + Q_3(n+1) &= Q_1(n) + Q_5(n). \end{aligned} \tag{90}$$

If next we eliminate the charges in the usual way and note that:

$$V_6(n) = -V_7(n) = E, \tag{91}$$

where E is the potential applied to the inductors, Eqs. (90) go over into two other equations, the left members of which take the form:

$$\begin{aligned} a_0V_0(n+1) + a_1V_1(n+1) + a_2E, \\ a_1V_0(n+1) + a_0V_1(n+1) - a_2E, \end{aligned} \tag{92}$$

and the right members of which take exactly the same form except that every a_i is replaced by a_i', and the argument $(n+1)$ by n. The fundamental electrostatic parameters of the machine are:

$$\begin{aligned} a_0 &= (0, 2\cdot0, 2), & a_0' &= (0, 2\cdot0, 4), \\ a_1 &= (0, 2\cdot1, 3), & a_1' &= (0, 2\cdot1, 5), \\ a_2 &= (0, 2\cdot6 - 0, 2\cdot7), & a_2' &= (0, 4\cdot6 - 0, 4\cdot7). \end{aligned} \tag{93}$$

If now we form the sum of Eqs. (92), and set therein:

$$S(n) = V_0(n) + V_1(n), \tag{94}$$

we have:

$$(a_0 + a_1)S(n+1) = (a_0' + a_1')S(n), \tag{95}$$

whence:

$$S(n) = S(0)r_0^n, \tag{96}$$

where:

$$r_0 = (a_0' + a_1')/(a_0 + a_1). \tag{97}$$

Forming similarly the difference of Eqs. (92), and setting therein:

$$D(n) = V_0(n) - V_1(n), \tag{98}$$

we have:

$$(a_0 - a_1)D(n+1) = (a_0' - a_1')D(n) + 2(a_2' - a_2)E. \tag{99}$$

It can readily be verified by substitution that the solution of the last equation is:

$$D(n) = Cr_1^n - 2\rho E, \tag{100}$$

where:

$$r_1 = (a_0' - a_1')/(a_0 - a_1), \tag{101}$$

$$\rho = (a_2' - a_2)/[(a_0' - a_1') - (a_0 - a_1)], \tag{102}$$

and C is an arbitrary constant, which can be evaluated by setting $n = 0$ in Eq. (100), which yields:

$$C = D(0) + 2\rho E. \tag{103}$$

Adding and subtracting Eqs. (96) and (100), after substituting therein for C its value as given by Eq. (103), yields finally as the solution of Eqs. (92):

$$\begin{aligned} 2V_0(n) &= S(0)r_0{}^n + (D(0) + 2\rho E)r_1{}^n - 2\rho E, \\ 2V_1(n) &= S(0)r_0{}^n - (D(0) + 2\rho E)r_1{}^n + 2\rho E. \end{aligned} \tag{104}$$

Investigation of the possible range of values of r_0 and r_1 shows that under all practical conditions both r_0 and r_1 are less than unity. Hence, irrespective of their initial values, on continued operation of the machine, the potentials of the receivers approach a constant value. Investigation of the possible range of values of ρ reveals that under ordinary conditions ρ will be greater than unity; hence the machine of Fig. 5 can be used to step up the constant potential applied to the receivers, which justifies the term "electrostatic voltage multiplier" applied to this type of machine.

The quantity ρ, which is the transformation ratio of the machine, is of especial interest. If we substitute for the electrostatic parameters appearing in Eq. (102) their values as given by Eqs. (93), and note that from the symmetry of the machine we have $(0, 2\cdot6) = (0, 2\cdot7)$ and $(0\cdot6) = (0\cdot7)$, the expression for the transformation ratio reduces to:

$$\rho = (4\cdot6 - 4\cdot7)/(0, 2\cdot2 - 0, 2\cdot3). \tag{105}$$

Noteworthy in connection with the last equation is that the capacity of the receivers, namely $(0\cdot0)$, does not enter into the expression for ρ: this means that the transformation ratio of the machine is independent of the capacity of the load.

Furthermore it is seen from Eqs. (104) and (94) that, if the initial potentials of the receivers are equal but opposite, the r_0 term will be absent altogether; hence this term represents the tendency for the receivers to assume equal but opposite potentials. As in practice the initial potentials will either be zero, or equal but opposite, it is seen that the term in r_1 is the more significant one, since it will govern the rapidity with which the potentials of the receivers build up to their final values.

On substituting in Eq. (101) for the electrostatic parameters appearing therein their values as given by Eqs. (93), and noting that from the symmetry of the machine we have $(0, 2\cdot4) = (0, 2\cdot5)$, we find that r_1 reduces to the form

$$r_1 = 1/(1 + f), \tag{106}$$

where f is given by:

$$f = (0, 2\cdot 2 - 0, 2\cdot 3)/(0, 2\cdot 0 - 0, 2\cdot 1). \tag{107}$$

Machines of the type of Fig. 5 have the further advantage that they can be connected in series, the transformation ratio of two machines connected in series being equal to the product of the transformation ratios of the separate machines. By connecting a sufficient number of machines in series, it is therefore possible to attain any multiple of a given potential.

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A RAPID METHOD OF INVERSION OF CERTAIN TYPES OF MATRICES.

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INTRODUCTION.

Many important problems in applied mathematics involve finding the inverse of a square non-singular matrix. Several methods have been devised to accomplish this (1). All of these methods entail considerable work if the matrix is of order higher than the third. The object of this paper is the development of a practical and time saving method which is particularly suited to a type of matrix frequently encountered. It is the matrix whose determinant is a continuant. That is, one which consists of zero elements everywhere except in the main diagonal and in the diagonals just above and below the main one. Furthermore, the predominant terms lie in the main diagonal.

Matrices of this type are encountered for example in vibration problems of systems having a finite number of degrees of freedom. They also occur in vibration, stability, or equilibrium problems of continuous systems which are solved approximately by replacing the differential equation by a difference equation (2).

It should be noted however that the method developed is applicable to a much more general type than the one just described. In fact it can be used to find the inverse of any matrix for which a certain infinite series of matrices derived below will converge.

GENERAL THEORY.

Let A be the square non-singular matrix of order n (n rows, n columns), the inverse of which is to be found. Partition A into sub-matrices as follows:

$$A = \left(\begin{array}{c|c} A_{11} & A_{12} \\ \hline A_{21} & A_{22} \end{array}\right)$$

such that A_{11} and A_{22} are square non-singular sub-matrices or order r and s respectively.

Let

$$B = \left(\begin{array}{c|c} A_{11}^{-1} & \mathbf{o} \\ \hline \mathbf{o} & A_{22}^{-1} \end{array}\right)$$

Then

$$AB = \left(\begin{array}{c|c} I_r & C \\ \hline D & I_s \end{array}\right) = I + \epsilon, \tag{1}$$

where

$$C = A_{12}A_{22}^{-1}$$
$$D = A_{21}A_{11}^{-1}$$

$$\epsilon = \left(\begin{array}{c|c} \mathbf{o} & C \\ \hline D & \mathbf{o} \end{array}\right),$$

I_r and I_s are unit matrices of order r and s respectively, $r + s$ being equal to n, the order of A. From eq. (1)

$$A^{-1} = B(I + \epsilon)^{-1}. \tag{2}$$

Assuming that $(I + \epsilon)^{-1}$ may be expanded as a convergent series, eq. (2) may be written

$$A^{-1} = B(I - \epsilon + \epsilon^2 - \epsilon^3 + \cdots), \tag{3}$$

where

$$\epsilon^2 = \begin{pmatrix} CD & \mathbf{o} \\ \mathbf{o} & DC \end{pmatrix}$$

$$\epsilon^3 = \begin{pmatrix} \mathbf{o} & CDC \\ DCD & \mathbf{o} \end{pmatrix}$$

$$\epsilon^4 = \begin{pmatrix} CDCD & \mathbf{o} \\ \mathbf{o} & DCDC \end{pmatrix}$$

etc.

Consequently

$$(I - \epsilon + \epsilon^2 - \epsilon^3 + \cdots)$$
$$= \begin{pmatrix} (I + CD + CDCD + \cdots) & -C(I + DC + DCDC + \cdots) \\ -D(I + CD + CDCD + \cdots) & (I + DC + DCDC + \cdots) \end{pmatrix}$$

If the latent roots of CD are less than unity, the two infinite series, $I + CD + CDCD + \cdots$ and $I + DC + DCDC + \cdots$ will converge to $(I - CD)^{-1}$ and $(I - DC)^{-1}$ respectively (1). Therefore

$$A^{-1} = \left(\begin{array}{c|c} A_{11}^{-1} & 0 \\ \hline 0 & A_{22}^{-1} \end{array}\right) \times \left(\begin{array}{c|c} (I - CD)^{-1} & -C(I - DC)^{-1} \\ \hline -D(I - CD)^{-1} & (I - DC)^{-1} \end{array}\right)$$

or

$$A^{-1} = \left(\begin{array}{c|c} A_{11}^{-1}(I - CD)^{-1} & -A_{11}C(I - DC)^{-1} \\ \hline -A_{22}^{-1}D(I - CD)^{-1} & A_{22}^{-1}(I - DC)^{-1} \end{array}\right).$$

It should be noted that all of the matrix products indicated may be carried out since the conformability rule is satisfied in all cases.

The given matrix A or the sub-matrices into which it is divided may always be so chosen that it will not be necessary to find the inverse of any matrix of order higher than the third. For example, if A were of the eighth order, the sub-matrices A_{11}, A_{12}, A_{21}, and A_{22} might be taken as fourth order matrices. Subsequently, $(I - CD)$ and $(I - DC)$ will be of the fourth order. The inverses A_{11}^{-1}, A_{22}^{-1}, $(I - CD)^{-1}$, and $(I - DC)^{-1}$ may be found by considering each to be divided into four matrices of the second order. Thus the inversion will depend upon finding the inverses of sixteen second order matrices. This can be

readily done. For the type of matrix specifically mentioned above still further simplification will ensue because of the number of zero elements involved. Again, if the matrix A is symmetric, advantage may be taken of the fact that A^{-1} is also symmetric. Or if matrix A is centro-symmetric, the author has shown (3) that the inverse may be found from the inverse of two matrices each of half the order of A if the order of A is even, or from the inverses of a matrix of order m and one of order $m + 1$ if A is of the order $2m + 1$. Each of these inverses may be found as indicated above.

EXAMPLE.

A simple example which serves to illustrate the method is furnished by the matrix which arises in connection with the finding of the natural frequencies of vibration of a set of equal masses attached at equal intervals to a weightless cord hanging vertically from an end. The matrix (in the case of four particles) to be inverted is shown partitioned.

$$A = \left(\begin{array}{rrr|r} 1 & -1 & 0 & 0 \\ -1 & 3 & -2 & 0 \\ 0 & -2 & 5 & -3 \\ \hline 0 & 0 & -3 & 7 \end{array}\right).$$

Then

$$A_{11}^{-1} = \frac{1}{6}\begin{pmatrix} 11 & 5 & 2 \\ 5 & 5 & 2 \\ 2 & 2 & 2 \end{pmatrix}; \qquad A_{22}^{-1} = \frac{1}{7}$$

$$C = A_{12}A_{22}^{-1} = \frac{1}{7}\begin{pmatrix} 0 \\ 0 \\ -3 \end{pmatrix}$$

$$D = A_{21}A_{11}^{-1} = [-1, -1, -1]$$

$$CD = \frac{3}{7}\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix}; \qquad DC = \frac{3}{7}$$

$$(I - CD) = \frac{1}{7}\begin{pmatrix} 7 & 0 & 0 \\ 0 & 7 & 0 \\ -3 & -3 & 4 \end{pmatrix}$$

$$(I - CD)^{-1} = \frac{1}{28}\begin{pmatrix} 28 & 0 & 0 \\ 0 & 28 & 0 \\ 21 & 21 & 49 \end{pmatrix}$$

$$(I - DC) = \frac{4}{7}$$

$$(I - DC)^{-1} = \frac{7}{4}$$

$$A_{11}^{-1}(I - CD)^{-1} = \frac{1}{12}\begin{pmatrix} 25 & 13 & 7 \\ 13 & 13 & 7 \\ 7 & 7 & 7 \end{pmatrix}$$

$$A_{22}^{-1}(I - DC)^{-1} = \frac{1}{4}$$

$$-A_{22}^{-1}D(I - CD)^{-1} = \left(\frac{1}{4}, \frac{1}{4}, \frac{1}{4}\right)$$

It is not necessary to calculate $-A_{11}C(I - DC)^{-1}$, since A is symmetric. A^{-1} will also be symmetric and the remaining terms may be filled in at once giving

$$A^{-1} = \frac{1}{12}\begin{pmatrix} 25 & 13 & 7 & 3 \\ 13 & 13 & 7 & 3 \\ 7 & 7 & 7 & 3 \\ 3 & 3 & 3 & 3 \end{pmatrix}$$

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ARMY AND NAVY NOTES.

X-Ray Automatically Checks Hand Grenade Fuses.—An automatic x-ray machine to accurately check the proper amount of powder in hand grenade fuses, essential to prevent explosions premature to the set time, has been devised by General Electric engineers and is now being used to test thousands of fuses daily. This machine, the first of its kind in the country, will automatically check fuses at the rate of 4000 an hour.

Each grenade fuse, slightly larger than the physician's thermometer and similar in appearance except that it is made of metal, contains two powder charges and a slow burning fuse. If in manufacture too small a charge is placed in any of these elements, the grenade is liable to explode as soon as the soldier releases his grip on the handle. When this trouble was detected, the Army called on all x-ray laboratories for help and the machine General Electric perfected is the only automatic one so far devised.

For checking, the fuses are set upright on a movable belt. This passes through the machine, allowing the perpendicular beam of a 100,000 volt x-ray to penetrate each fuse and cast its glow on a fluorescent screen, above which is a phototube of "electric eye." So long as the fluorescent glow remains constant, nothing happens and the fuses pass through. However, should a fuse with a light powder charge pass over the x-ray beam the phototube detects the change in the fluorescent glow, automatically rings a bell, flashes a red light, places a dab of red paint on the top of the fuse and records the "dud" graphically on a meter chart. This four way check makes it impossible for a bad fuse to get by without detection.

When the fuses arrive they are packed in wooden boxes, each containing 200. In three minutes they have been unpacked, x-rayed and are back in the boxes ready for shipment.

R. H. O.

THE SYNTHESIS OF THE ETHYL ESTERS OF SOME 2-OXO- AND 2-THIO-1,2,3,4-TETRAHYDRO-5-PYRIMIDINECARBOXYLIC ACIDS.

BY

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Prior to the report on the mechanism involved in the inhibition of bacterial growth by sulfanilamide,[1] research on chemotherapy in bacterial infections was decidedly empirical. Indeed, since the days of Ehrlich the search for anti-bacterial drugs has been largely dominated by the trial and error method. Although many of our most effective chemotherapeutic agents have been employed in combatting infection for years, knowledge regarding the precise manner in which they function is meager.

Micro-organisms, in order to grow, multiply and function in their characteristic manner, must synthesize or obtain preformed from their environment certain chemical substances called essential metabolites. These substances, as their name implies, play an important role in the chain of syntheses necessary for normal cell metabolism and growth. Many saprophytic micro-organisms are endowed with the ability to synthesize these essential substances from such simple compounds as ammonia, monosaccharides and mineral salts. Most pathogens on the other hand, presumably as the result of their adaptation to parasitic existence, have lost the power to synthesize these substances which are necessary for their normal functioning. An essential metabolite which cannot be synthesized by a micro-organism and which consequently must be obtained from the environment is referred to as a growth factor for that organism. Although little or nothing is known regarding the mechanism of these syntheses, data accumulated in recent years indicate that they are achieved in steps, each reaction being catalyzed by a specific enzyme or series of enzymes, coenzymes and activators. It is well known that in reactions of this type, certain substances closely related in chemical configuration to one of the substrates invariably inhibit the reaction to a certain extent by competing with the normal substrate for the enzyme involved. Fildes [2] has suggested, therefore, that research in this phase of chemotherapy might profitably be directed to the preparation of derivatives of known growth factors which are similar enough in chemical configuration to react with the enzyme involved but sufficiently unrelated to be devoid of metabolic activity. Bacterial action would thus be inhibited by compounds of this type by virtue of their interference with the synthesis of a substance essential to the growth and activity of the parasite. That this approach is well-

advised has been strikingly demonstrated by the large number of new and effective bacteriostatic agents that have been developed during the past few years.

Richardson [3] in 1936 discovered that uracil was essential for anaerobic growth of pathogenic staphylococci. A minute amount, 0.2 gamma per milliliter, sufficed for abundant anaerobic growth suggesting that this factor is necessary for the synthesis of a substance, probably vitamin-like in nature, required in extremely small amounts by the cell. Pyrimidines are also components of the cell nucleus and of the nucleoproteins of all filterable viruses thus far sufficiently purified for chemical analysis. In spite of their wide distribution and probable importance in living systems, the physiologic action and pharmacologic properties of this interesting class of compounds have received scant attention. In view of the fact that viruses have proved refractory and the staphylococci only moderately susceptible to the action of the chemotherapeutic agents now available, a series of pyrimidine derivatives is being studied in this Laboratory in an effort to develop drugs effective against these parasites.

Biginelli [4] in 1891 discovered that an aldehyde will condense with urea and a β-ketone ester in alcohol with the smooth formation of a 2-oxo-1,2,3,4-tetrahydropyrimidine. Apparently little attention was paid to this reaction until 1929, when Hinkel and Hey [5] resumed the work and varied the experimental procedure in a manner which they considered favorable for the formation of dihydropyridines according to the Hantzsch reaction. Although these investigators did succeed in synthesizing dihydropyridines by using these reagents, the main product in most cases was a tetrahydropyrimidine as originally formulated by Biginelli. Folkers and Johnson [6,7] in 1932 began a systematic study of the Biginelli condensation and in a series of papers demonstrated the mechanism involved, introduced several improvements in experimental technique and described the preparation of a number of new compounds of this type.

Several new ethyl 2-oxo- and 2-thio-4-R-6-methyl-1,2,3,4-tetrahydro-5-pyrimidinecarboxylates (see Table I) were prepared in this Laboratory by a modification of the Biginelli condensation.[6] Further synthetic work is being conducted at the present time. The results of this work as well as the effect of these compounds in experimental bacterial and virus infections will be reported at a future date.

EXPERIMENTAL.

The ethyl 2-oxo-4-R-6-methyl-1,2,3,4-tetrahydro-5-pyrimidinecarboxylates were prepared by refluxing a mixture of 0.1 mole of urea, 0.15 mole of ethyl acetoacetate and 0.1 mole of the appropriate substituted benzaldehyde in 25 ml. absolute ethanol for varying periods of time. Concentrated hydrochloric acid (4 drops) was employed to

TABLE I.

Properties and Analyses of the Substituted Pyrimidines Prepared.

Name.	Formula.	Substituted benzaldehyde employed.	Reaction time (hours).	Yield, per cent.	M.P. (uncor.) ° C.	Nitrogen, per cent.	
						Calcd.	Found.
ETHYL 2-OXO-4-R-6-METHYL-1,2,3,4-TETRAHYDRO-5-PYRIMIDINECARBOXYLATES R =							
2-Chlorophenyl	$C_{14}H_{15}N_2O_3Cl$	2-Chloro	3	51	214	9.51	9.43
2-Hydroxy-5-chlorophenyl	$C_{14}H_{15}N_2O_4Cl$	2-Hydroxy-5-chloro	3	30	203	9.02	8.90
3,4-Diethoxyphenyl	$C_{18}H_{24}N_2O_5$	3,4-Diethoxy	3	55	165	8.05	7.93
4-Dimethylaminophenyl	$C_{16}H_{21}N_3O_3$	4-Dimethylamino	2.5	65	231	13.86	13.70
4-Diethylaminophenyl	$C_{18}H_{25}N_3O_3$	4-Diethylamino	3	72	199	12.69	12.51
ETHYL 2-THIO-4-R-6-METHYL-1,2,3,4-TETRAHYDRO-5-PYRIMIDINECARBOXYLATES R =							
3,4-Dimethoxyphenyl	$C_{16}H_{20}N_2O_4S$	3,4-Dimethoxy	3	48	231	8.33	8.07
3,4-Diethoxyphenyl	$C_{18}H_{24}N_2O_4S$	3,4-Diethoxy	3	52	125	7.69	7.46
4-Dimethylaminophenyl	$C_{16}H_{21}N_3O_2S$	4-Dimethylamino	3	45	197	13.16	12.66
4-Diethylaminophenyl	$C_{18}H_{25}N_3O_2S$	4-Diethylamino	3	54	200	12.10	11.90

catalyze the reaction. The sulfur analogs were prepared in the same manner from thiourea, ethyl acetoacetate and the substituted benzaldehyde. Condensation was effected smoothly in all cases. The crystalline pyrimidines separated on chilling the solution to 0° C. and were purified by repeated recrystallization from ethanol. All of the compounds were very soluble in acetone and in alcohol, slightly soluble in ether and relatively insoluble in water. The yields obtained were not appreciably increased by varying the ratio of reagents, increasing the concentration of the catalyst or prolonging the reflux-period.

SUMMARY.

Some ethyl 2-oxo-4-R-6-methyl-1,2,3,4-tetrahydro-5-pyrimidinecarboxylates and several of the corresponding 2-thio-compounds were prepared by a modified Biginelli condensation.

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ARMY AND NAVY NOTES.

Soap Use in Plastics.—(*The American Perfumer and Essential Oil Review*, Vol. 45, No. 9.) The new and the old, plastics and soap today are combining in a number of products said to give superior results over the former products they are now displacing. A large variety of resins, synthetic and natural, are being dispersed in water by means of ordinary soap to be used as paints, rubber cement extenders, textile waterproofing and finishing agents, car polishes and still other diversified fields. These new products, by saving large quantities of organic solvents, by easing the drain on our rubber stocks, and by being in some instances more effective, make a hidden, yet exceedingly valuable contribution to the war effort.

One of the most revolutionary of the plastic-soap combinations is the recently perfected water-base paint. In use by the Army, Navy, and large war plants, this type of paint is free from poisonous, expensive, and inflammable organic solvents, is readily mixed up with a readily available substance—water—has high covering power, and great resistance to wear. Moreover, these paints dry in a few hours and may be applied to damp surfaces. Pigments, plasticizers and other materials are generally mixed in with the synthetic resin.

A number of the resin dispersions can be used as textile impregnating mediums, giving water-proofing, crease-proofing, or simple sizing effects. A modern plastic, polymerized ethylene, may now be used for this purpose (U.S.P. 2,290,794). This wax-like substance is too insoluble in commercial solvents, and also has too high a melting point to be useful for impregnating. However, by working soap and a protective colloid into the hot polymer, and then mixing with water, an aqueous dispersion of wax results, bringing it into a form which has many applications.

Another recent combination of synthetic resins with soap has been disclosed in U.S.P. 2,289,392, which describes a new type of automobile polish. A condensation product of castor oil and oleic acid is dispersed in a petroleum hydrocarbon, which in turn is dispersed in water by means of soft soap. A special tar cutter, such as orthodichlorbenzene, and gums to improve the action of the soap are also added.

R. H. O.

REMOVAL OF MERCURY FROM SOLUTIONS OF MERCURIC NITRATE BY MERCURIC SULFIDE.

BY

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The property of freshly precipitated mercuric sulfide to adsorb or combine with other molecules was shown by qualitative tests made by Müller and privately communicated to Wagner.[1]

The tests were repeated by adding freshly precipitated mercuric sulfide to solutions of mercuric nitrate. The suspensions were well shaken and filtered. The filtrates gave a negative test for mercury only when the calculated amount of mercury in the solution did not exceed 2 mg. per 200 mg. of mercuric sulfide in a volume of 100 cc.

This investigation was initiated with the purpose of obtaining, quantitatively, further information on the mechanism of the reaction taking place in the removal of mercury from solutions of mercuric nitrate by freshly precipitated mercuric sulfide.

EXPERIMENTAL.

All chemicals were C.P. grade and were purified only where it was found necessary.

Mercuric sulfide was prepared from an accurately measured volume of a standard solution of mercuric nitrate. The solution was saturated with hydrogen sulfide, the precipitate weighing 0.1835 g., was filtered on qualitative filter paper and washed with water until the last 5 cc. gave a negative test for hydrogen sulfide. The wet sulfide was transferred from the paper to a 125 cc. Erlenmeyer flask by means of a stream of water. After adding mercuric nitrate and adjusting the solution to the proper concentration of nitric acid (0.02N) and to the desired volume (100 cc.), the flask was tightly stoppered and emersed in an electrically regulated constant temperature water bath maintained within $\pm 0.1°$ of the chosen value (32.5°), and allowed to remain there for a given time (24 hours) with occasional shaking at constant intervals.[2] The mercury remaining in the solution was determined by the thiocyanate method. The difference in the amount of mercury taken and that remaining after a given time was calculated as the amount removed from solution by the mercuric sulfide. No visible evidence of hydrolysis of the mercury salt could be detected when allowing solutions of mercuric nitrate to stand under the same conditions in the absence of mercuric sulfide.

METHODS OF ANALYSIS.

Determination of Mercury.—Aliquot portions of the centrifuged solution were titrated with standard ammonium thiocyanate solution, ferric alum used as the indicator. A solution of ammonium thiocyanate, 0.01N, was measured from calibrated microburets in the titration of small amounts of mercury. The solution of ammonium thiocyanate was standardized against an amount of mercury approximately the same as that remaining in the aliquot portion. The volume of the solutions and the amounts of indicator were the same in the standardization as in the determination. The accuracy of the method was tested by titrating known amounts of mercury. These results are given in Table I.

TABLE I.

Titration of Small Amounts of Mercury.

Mercury taken, g.	Mercury found, g.	Error, %
0.00156	0.00153	−1.9
	0.00155	−0.7
	0.00154	−1.3
0.00078	0.00079	+1.3
	0.00077	−1.3
	0.00080	+2.5
0.00039	0.00038	−2.5
	0.00040	+2.5
	0.00038	−2.5

DETERMINATION OF NITRIC ACID IN MERCURIC NITRATE SOLUTION.

The method of Pelouze-Fresenius,[3] using ferrous chloride and potassium permanganate, was found to give sufficiently accurate results for the determination of nitrate in the presence of mercury, but to be time consuming because of the necessity of weighing and dissolving samples of iron for each determination. A modification of the Pelouze-Fresenius method was made in which a solution of ferrous sulfate was substituted for iron. The method was tested by determining the nitrate content of potassium nitrate alone and in the presence of mercuric nitrate (Tables II and III). The nitric acid concentration of the mercuric nitrate

TABLE II.

Determination of Nitrate.

Nitrate (NO_3) taken, g.	Nitrate (NO_3) found, g.	Error, g.
0.14270	0.14250	−0.00020
	0.14220	−0.00050
0.05549	0.05535	−0.00014
	0.05541	−0.00008
0.02864	0.02914	+0.00050
0.01207	0.01194	−0.00013
0.01084	0.01092	+0.00008

TABLE III.

Determination of Nitrate in the Presence of Mercury

Nitrate (NO_3) taken as $Hg(NO_3)_2$, g.	Nitrate (NO_3) taken as KNO_3, g.	Total nitrate (NO_3) taken, g.	Nitrate found, g.	Error, g.
0.10233	0.05559	0.15792	0.15769	−0.00023
0.01916	0.10387	0.12303	0.12297	−0.00006
0.01874	0.10763	0.12637	0.12705	+0.00068
0.02046	0.10845	0.12891	0.12911	+0.00020

solution was calculated from the values obtained for the mercury and nitrate concentration.

DISCUSSION.

The removal of mercury from dilute solutions of mercuric nitrate by mercuric sulfide follows the Freundlich adsorption isotherm. The curves in Fig. 1 are similar to those obtained for gaseous adsorption and

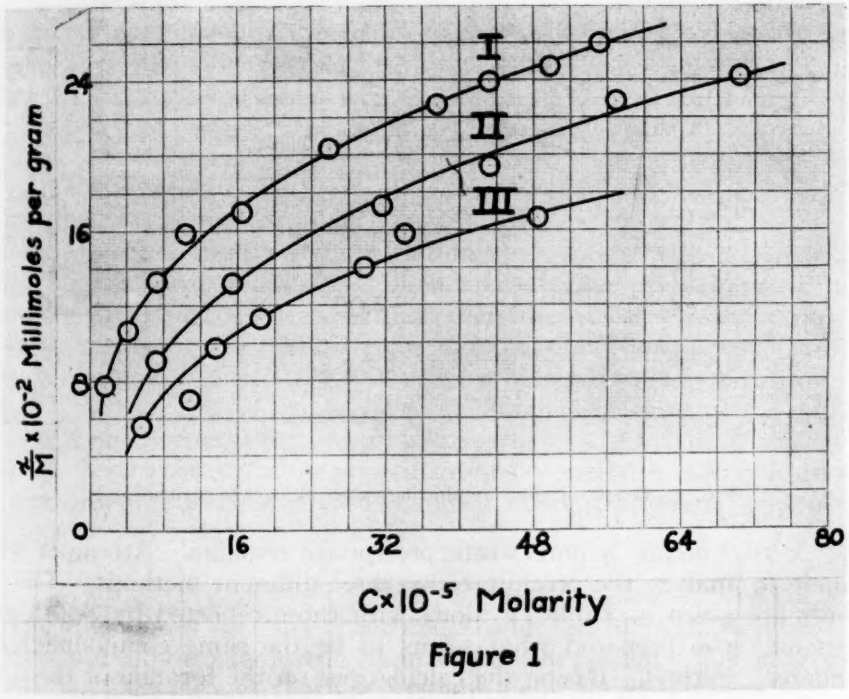

FIG. 1. Adsorption curves for the removal of mercury from dilute solutions of mercuric nitrate by mercuric sulfide. I. Hydrogen sulfide removed by filtering and washing the mercuric sulfide with distilled water. II. Hydrogen sulfide removed by boiling the mercuric sulfide suspension. III. Hydrogen sulfide removed by filtering and washing the mercuric sulfide with a dilute acid permanganate solution.

true physical adsorption from solution. When the data for Curve I are replotted, the relation of log x/m vs. log C gives a straight line as shown in Fig. 2. The same relation exists for Curves II and III with a little different slope.

At higher concentrations of mercuric ions the curve does not follow the isotherm, nor does the relation of log x/m vs. log C exist. As the concentration is increased from 7.6×10^{-3} to 2.2×10^{-2} molar, there is a gradual change in the color of the mercuric sulfide from black to varying shades of grey until finally, at concentrations greater than

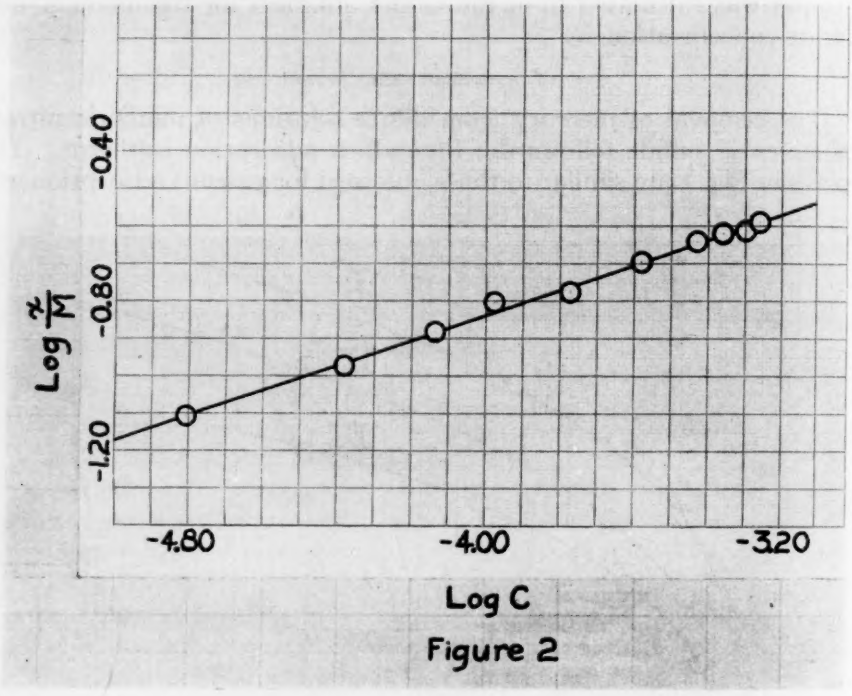

FIG. 2. Graph obtained by plotting values of log x/m against log C.

4.7×10^{-2} molar, a pure white precipitate remains. Attempts were made to analyze the precipitate by three different methods. The results are given in Table IV along with those reported by Smith and Semon [4] who prepared what seems to be the same compound by a different method. Basing the calculations on the formula of the compound mercuric nitratodisulfide $2HgS \cdot Hg(NO_3)_2$, the results are high for mercury and low for sulfur. Smith and Semon state that the poor analytical results are due to the fact that the compound is amorphous and somewhat unstable, and is generally contaminated with mixed or adsorbed substances.

TABLE IV.

Analysis of the White Precipitate.

Method.	Mercury, %.	Sulfur, %.	Nitrate, %.
I	76.89	7.29	15.82
II	76.84	7.49	15.67
	76.76	7.25	16.00
III	76.89	7.64	15.47
	76.97	7.76	15.27
Smith and Semon	75.00	—	14.97
Theory	76.19	8.12	15.69

The amount of mercury removed from solution increases with time of standing; however, it appears that very little if any is removed from solution after 24 hours. In order to determine if true adsorption equilibria are attained in this time, mercuric sulfide-mercuric nitrate solutions were brought in contact with pure water adjusted to the proper acidity (.02N) and allowed to stand under the same conditions as given in the procedure. At low concentrations of mercuric nitrate the amounts of mercury found in solution were within fair agreement with the amounts obtained by approaching the equilibrium from above, that is, by the removal of mercury from solution. At higher concentrations of mercuric ions the reaction was found to be irreversible.

It is a well known fact that the empirical relation shown by the Freundlich adsorption isotherm may also formally describe processes other than surface adsorption. Also in systems with a fairly open structure, such as freshly precipitated mercuric sulfide, true adsorption usually takes place rapidly. A slow rate of adsorption indicates a dense and fairly inaccessible structure; therefore, the slow reaction rate, as found in this investigation, may be an indication, though not a proof, of the existence of some other process or processes besides true adsorption. However, the fact that the data obtained in this investigation show that the Freundlich adsorption isotherm and an apparent adsorption equilibria exist with low concentrations of mercuric ions indicates an adsorption process, whereas, at higher concentrations of mercuric ions, compound formation takes place.

SUMMARY.

The removal of mercury from dilute solutions of mercuric nitrate by mercuric sulfide is indicative of an adsorption process. The relation of $\log x/m$ vs. $\log C$ shows that the Freundlich adsorption isotherm exists.

At higher concentrations of mercuric nitrate a reaction takes place with the mercuric sulfide forming a compound of the possible formula $2HgS \cdot Hg(NO_3)_2$ mercuric nitratodisulfide.

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Note: This paper was abstracted from the dissertation presented by George H. Spaulding to the faculty of the Graduate School of the University of Pennsylvania in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June 1942.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

SIGNALING MIRRORS.

When adrift on a liferaft, if the weather is clear, one's best chance of attracting the attention of rescue craft which come into view is by reflecting a beam of sunlight from a mirror. United States craft which travel overseas now carry signaling mirrors in their lifeboats and liferafts. To produce a strong signal visible over a range of several miles the mirror must be nearly flat, not warped; and to make the reflected beam easy to aim, the mirror must include a simple, accurate aiming device; this usually takes the form of a sighting hole in the middle of the mirror.

Experiments have been conducted at the Bureau both with metal and with glass mirrors in an effort to find out how flat they should be to produce a strong signal, and also which of six different methods of aiming the reflected beam is the most effective. An instrument for measuring the flatness of mirrors has been constructed, and flatness tolerances, established by the range tests for inclusion in purchase specifications, have been expressed in terms of this newly developed planarity meter. Furthermore, an improved form of metal mirror has been developed which can be aimed perhaps even more accurately than the best glass mirrors.

DETERMINING INDICES OF REFRACTION AND DISPERSION OF OPTICAL GLASS BY IMMERSION.

Conditions of wartime manufacture of optical glass have made desirable the development of an accurate and rapid method for determining the indices of refraction and dispersion of the glass. An immersion method having these characteristics is described by Conrad A. Faick and Bernard Fonoroff in the February *Journal of Research* (RP 1575). The apparatus makes use of the double diaphragm system for obtaining oblique illumination. The average error in the determination of the indices of refraction of glass gased upon 144 determinations is 2×10^{-5} units of index; the maximum error found in these measurements is 5×10^{-5} units. The average error in the calculated v values

* Communicated by the Director.

Note: As evidence of the reader interest contained in these "Notes," we have recently learned that one of our subscribers found here the answer to a research problem on which his company had spent a considerable amount, thereby eliminating the necessity for further expenditures in connection with the question. We were pleased to hear that the "Notes" were of some benefit in this case. THE EDITORS.

is 0.1; the maximum error, 0.8. Complete measurements of the index of refraction and the calculations of the v values may be made in approximately 1 1/2 hours.

WEAR OF TIRE TREADS.

During the height of the emergency period, when all possible materials were being considered for the treads of pneumatic tires, determinations were made at the Bureau of the rates of wear of several tread materials by weighing the tire at intervals and noting the loss in weight. This method involved a minimum amount of work and required relatively few miles of driving to obtain a reasonably reliable rate of wear which could be extrapolated to predict the life of the tread. The results obtained showed the method to be feasible for passenger car tires and, in addition to yielding data on the value of different materials for treads, it indicated the effect of other details, such as the location of the tires on the car and the alignment of the wheels. In the February *Journal of Research* (RP 1574), Frank L. Roth and W. L. Holt give data on five different tread materials, including pre-war natural rubber treads. The rate of wear of the least resistant tread material was eight times that of the most resistant material. GR-S type synthetic —the principal rubber being manufactured—appears from these tests to be nearly as good as natural rubber.

COMMERCIAL STANDARD FOR TIRE REPAIRS BY VULCANIZATION.

Requirements which the industry considers representative of a high standard for repairs by vulcanizing of passenger, truck, and bus tires, are set forth in Commercial Standard CS110-43, now available in printed form.

The standard covers inspection of the injured tire and the conditions necessary for satisfactory repairing; quality of materials; workmanship; curing methods and equipment; and guarantee to the user.

The establishment of the standard was requested by the National Association of Independent Tire Dealers, and the specifications were first drafted by a representative group of tire repair material manufacturers' engineers in Akron, Ohio, on October 15, 1942.

The specifications and methods adopted by those attending the conference were circularized for comment among a large number of manufacturers of mold equipment, tire repair shops, large national users, and Government agencies. After adjustment in the light of the information thus obtained, the recommended commercial standard was circularized to all known interested organizations for written acceptance. The accepted standard, as now published, includes the membership of the Standing Committee for future revisions of the standard, a brief history of the project, and a list of firms, organizations, and individuals

that have accepted the specifications as their standard of practice. Copies are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. The price is 5 cents.

WEATHERING LOSSES OF GALVANIZED STEEL.

For nearly 30 years the Bureau has coöperated with the American Society for Testing Materials in the corrosion testing of iron and steel. These tests have been almost exclusively in the nature of long-time exposures of carefully selected commercial products. An important current project of this kind is concerned with wire and wire products—fencing, barbed wire, highway safety cables, etc. Data recently reported have a bearing on the rate at which zinc is removed from a galvanized steel surface (steel wire) as a result of continuous exposure to weathering influences. As part of its coöperation in this series of tests, the Bureau prepared a set of 400 wire specimens of carefully determined weight and length. These were built into the exposure-test frames and exposed at various test sites under distinctly different atmospheric conditions—industrial, rural, and marine. At intervals during the progress of the tests, selected specimens are removed from the frames and returned for cleaning, remeasurement of length, and reweighing. A comparison of the current weight per unit length with the initial weight per unit length gives definite information on the loss sustained by the protective zinc coating.

Data just secured on wire exposed at a rural test site in central Pennsylvania indicate that this "above-average" grade of galvanized fence wire lost approximately 1/3 of its protective zinc coating in about 6 years. Stated in other words, under normal service conditions, at that location, a fence fabricated from such wire should not show evidence of severe corrosion damage until after 18 or 20 years had elapsed.

DISTILLED WATER SYSTEM FOR TESTING LABORATORY.

An interesting feature of the equipment in the Bureau's new Materials Testing Laboratory is a completely automatic system for preparing distilled water. The controls are designed to start the still when the level of distilled water in the reservoir reaches a predetermined minimum and to shut it off when the reservoir is filled. The water in the boiler is automatically discharged from time to time to prevent excessive accumulation of impurities. If these controls operate well, they will minimize the attention required for the production of distilled water for the several laboratories in the building.

The distributing line from the reservoir to the different floors of the building is made of an alloy not previously used, so far as is known

at the Bureau, in distilled water systems. This is tin alloyed with about $3\frac{1}{2}$ per cent. of silver. Tests made several years ago showed this alloy to be much superior in mechanical properties, especially strength and freedom from creeping, to the pure tin commonly used for distilled water pipes. No evidence was obtained that distilled water is contaminated by contact with the alloy. The experimental use of the silver alloy in this relatively short line should furnish definite information concerning its suitability for future installations.

REACTIONS IN THE CARBOHYDRATE FIELD.

An examination of the literature of the carbohydrates reveals many reactions involving the migration of double bonds and the formation of compounds which appear only remotely related to the parent carbohydrates. Heretofore, no attempt has been made to correlate these reactions; they have been considered for the most part as a group of unrelated facts.

In RP1573 in the February *Journal of Research*, Horace S. Isbell endeavors to show how the peculiar properties of systems involving double bonds may be explained by the migration of electron pairs with the addition and cleavage of ions. By applying a few general principles, explanations are obtained for the formation of the four classes of saccharinic acids from the 1,2-, and 2,3-, and 3,4-enediols, for the formation of diacetylkojic acid from acetylglucosone, for the conversion of triacetylglucal to diacetylphseduoglucal, for the conversion of tetramethyl-1, 2-glucoseen to ω-methoxymethylfurfural, and for the formation of furfural and levulinic acid.

ANOMALIES IN THE CRYSTALLINE STRUCTURE OF MICA.

Present conditions, particularly the scarcity or non-availability of various raw materials, have forced critical examinations of many of these materials, accompanied by tests to clear up any obscure points. Although interesting information has thus been obtained, the practical utility of much of it is often not evident at the moment. The statement applies with particular force to recent structural examinations of mica. As a supplement to studies of the thermal expansion of this substance (which has shown some irregularities in this property), X-ray structural studies of mica from two widely different sources were carried out.

In these studies, Brazil mica showed the phenomenon of double diffraction spots in both the "as-received" and the "heat-treated" condition. The result was interpreted as indicating a "mosaic" structural condition. Such a condition may be loosely thought of a structural block pattern independent of, and contained within, the normal crystalline pattern. This structural behavior was not found in Madagascar

mica, either in its ordinary state or after "heat treatment." Instead, the condition of "asterism" (indicative of "disturbed" or irregular atomic lattice conditions) was more intense after heat treatment.

X-ray or Laue examinations conducted at various elevated temperatures up to 300° C., confirmed the observations by showing that the mosaic condition was intensified in the Brazil mica on heating, together with its disappearance on cooling. These observations are consistent with those of thermal expansion carried out on the same materials. The significance of the difference in the structural condition and behavior of the two types of mica is as yet an open question, so far as the practical utilization of mica is concerned.

ARMY AND NAVY NOTES.

Cycleweld—A New Bonding Process.—(*Modern Plastics*, Vol. 21, No. 1.) Plastics' long awaited entry into major structural applications in automobiles, airplanes, and houses is an immediate post-war possibility as the result of a war time development which until recently has been closely guarded by the military. This is Cycleweld, a new process for permanently bonding together and to each other metal, wood plastics, ceramics, fiber board and rubber in any desired combination to form structures that are stronger, lighter and cheaper than those joined by conventional methods.

The Chrysler Corp., which developed the process in its Production Research Department, is now in production on scores of Cycleweld parts for fighter planes and bombers, and 30 other companies in war work are using Cycleweld.

Cycleweld over the last year has been thoroughly tested and accepted for aircraft applications, in which it unites aluminum alloy, wooden and rubber parts without riveting or welding and at such strength that no Cycleweld bond ever has been broken by vibration. In all tests the metals or other materials joined have given way before the bond.

Cycleweld cement itself is a thermosetting plastic, the exact composition of which cannot be revealed at this time. The operation of Cyclewelding is accomplished by putting the synthetic plastic cement on the surfaces to be connected and then applying heat and pressure to the joint. The process can be used on any aircraft or similar subassembly to which moderate pressure can be applied. The name Cycleweld is derived from the fact that the process is essentially the cycle of pressure and heat required to produce a plastic "weld." In the usual sense of the word, there is no welding involved.

Two distinct types of the cement are now being produced. One is used to bond any material except rubber; the other will bond any material to natural and most synthetic rubbers.

With the first type there are many possible means of applying the necessary heat and pressure. Chrysler suggests the use of pressure fixtures, such as hydraulic presses, spring loaded mechanical presses or spring loaded clamps; distribution pressure pads; and dies made of any material which will withstand curing temperatures for an indefinite curing cycle.

The second type bonds materials to rubber at a considerably lower pressure, with 25 p.s.i. generally being recommended. Heating methods for both types include ovens, electrically and steam heated plattens, internal resistance, radio frequency, infrared lamps, etc.

R. H. O.

THE FRANKLIN INSTITUTE

Stated Monthly Meeting, February 16, 1944

The audience stood at attention while the National Anthem was played.

Mr. Charles S. Redding, President, then called the meeting to order and stated that, due to unforeseen difficulties, the January number of the JOURNAL had not come out in time to legitimately enable the members to vote on the December minutes of the Institute.

At this meeting it was therefore duly moved and seconded that the December minutes, as printed in the January number of the JOURNAL, be approved as printed.

Dr. Henry B. Allen, Secretary, was then called upon to make his report. He stated that since the last meeting the following additions to membership have occurred:

Active	101
Associate	26
Student	27
Library Sustaining	3
	157
Total Institute Membership	5,824

Dr. Allen then proposed the names of the two Franklin Medalists for 1944, for Honorary Membership in The Franklin Institute, in accordance with custom:

Dr. William David Coolidge,
Vice-President and Director of Research,
General Electric Company,
Schenectady, New York
and
Dr. Peter Kapitza,
The Institute for Physical Problems,
Moscow, Union of Soviet Socialist Republics

Upon motion, duly seconded and carried, these two gentlemen were elected to Honorary Membership.

Mr. Redding then introduced the speaker of the evening, Mr. Richard P. Price, Vice-President, Hammermill Paper Company, of Erie, Pennsylvania, and stated that his subject would be "Ancient and Modern Usage of Paper."

Mr. Price told of the material and methods used in making paper by the Chinese and other Asiatic people. He discussed the advent of the process into Europe and the improvements there made. He explained the developments resulting in pulp being made from wood and finally into paper which is so extensively used today for cultural and non-cultural purposes. After the paper, a number of questions were asked by a very interested audience.

The paper will be published in full in a subsequent number of the JOURNAL.

The meeting adjourned at 9:40 P.M.

THE NEWCOMEN MEDAL AWARD *

The annual Newcomen Society Dinner was held at The Franklin Institute on the 238th anniversary of the birth of Benjamin Franklin. The occasion was made memorable by the award of the first Newcomen Medal, to Rear Admiral Harold G. Bowen, U.S.N., formerly Chief of Bureau of Engineering, Navy Department, and Technical Adviser to the Secretary of the Navy.

Unfortunately Admiral Bowen was ill in California at the time of the award. The medal was therefore given in absentia, and received by his Aide, Commander R. E. W. Harrison, U.S.N.R. At the instigation of friends, the ceremony was privately broadcast to Admiral Bowen, who was thus enabled to hear the exercises.

The program follows:

CHARLES S. REDDING, President, The Franklin Institute, Presiding.

MR. REDDING: Admiral Bowen, in the name of, and as President of The Franklin Institute of the State of Pennsylvania, I open this Coast-to-Coast broadcast, addressed to you in your hospital bed on the Pacific Coast at Los Angeles. This quite unusual and very happy private radio communication has been made possible by some of your friends who wish you now to hear, and so take part in, this distinguished occasion, namely: the first award of one of America's highest distinctions in the field of Engineering and Technology, about to be bestowed upon your, regrettably in absentia, for your outstanding contributions in the field of Steam.

The notable occasion of this large gathering here in the great Hall of The Franklin Institute on the Benjamin Franklin Parkway in Philadelphia, is the annual National Newcomen Dinner, honoring the Birthday of Dr. Benjamin Franklin. It is his 238th Birthday today, Monday, January 17, 1944.

The Newcomen guest of honor, who later this evening will speak on the life and work of Dr. Franklin, is Dr. Carl Van Doren, internationally known biographer of Benjamin Franklin. Through pleasant coincidence, Dr. Van Doren, who is seated near me here tonight, is a member of the New York Committee in The Newcomen Society of England, of which distinguished British Society you and I likewise are members.

However, the special purpose of this radio channel across America, extended for tonight between us in Pennsylvania and you in California, is to provide a vehicle whereby you may "listen in" on that part of tonight's exercises which relates to the *first* award of a very high honor. You, Sir, are the recipient.

* See JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 236, No. 4, page 400, for description of Medal.

In the sequence of this radio program, I call first upon one who is widely known through the United States, who himself will explain the gracious task which he tonight performs.

Wherefore, I recognize first Mr. William Moorehead Vermilye of New York.

MR. VERMILYE: Mr. President, The Newcomen Society of England is honored to have established this NEWCOMEN MEDAL, to be awarded by The Franklin Institute of the State of Pennsylvania, in recognition of *outstanding achievement in STEAM*. It altogether is appropriate that this be done, because Thomas Newcomen of Dartmouth in Devonshire, in *1711*, developed the *first* practical Steam Engine, first used to pump water from the mouth of mines in Cornwall. This was *more than 50 years* before James Watt did his world-famous work upon the Watt Engine.

As President of The British Newcomen at London, as a member of the Board of Managers in The Franklin Institute of Pennsylvania, and as Chairman of The National Franklin Committee—I have a *triple* satisfaction now in presenting to you, President Redding, this *the first* Newcomen Medal.

You will sense my further satisfaction in that one of my dearest friends, a distinguished Naval Officer, the Chairman of the Washington Committee in American Newcomen, has been chosen by the Institute to receive the first honor.

MR. REDDING: Mr. Vermilye, in the name of The Franklin Institute, and on behalf of its Board of Managers and the Committee on Science and the Arts, administering the award of medals, I gratefully accept this Newcomen Medal. It will be our grave responsibility, in observing our own high standards, to see that the Medal ever is bestowed in keeping with those high standards which prompted its foundation by The Newcomen Society of England. We feel we already have shown good faith and discerning judgment by selecting Admiral Bowen as our first recipient.

Next, I call upon the Chairman of our Newcomen Medal Committee in the Board of Managers of the Institute, Mr. Morton M. Price of Philadelphia, the Institute's Treasurer, asking him to read the citation of our Committee on Science and the Arts, recommending this eminent choice. . . . Mr. Price.

MR. PRICE: Mr. President, in the capacity you have just indicated, it is my great pleasure to read the citation by which Rear Admiral Harold G. Bowen, United States Navy, distinguished naval officer and engineer, is now being honored. The citation is as follows:

"In consideration of his long record of service with a group of engineers, whose work is now such a vital part of the life of our nation, and particularly in view of his outstanding advocacy of the advance in steam engineering in this branch of our national defense, as represented

by the increase in steam pressures and temperatures used on equipment installed on its ships."

And now, it is my privilege to present to you, to receive the first Newcomen Medal, on behalf of Admiral Bowen, who hears each word we are saying, his friend and brother officer and Aide, Commander R. E. W. Harrison, United States Navy Reserve, who graciously has come from Washington for this purpose. . . . Commander Harrison, I present you to the President of The Franklin Institute.

MR. REDDING: Commander Harrison, by virtue of the power vested in me as President of The Franklin Institute, I have the honor to hand to you the Newcomen Gold Medal, with the Certificate and Report which accompanies it, awarded to Admiral Bowen. Will you see that these safely reach him.

COMMANDER HARRISON: Mr. President, Members and Guests of Newcomen:

It is my high honor and privilege to receive and acknowledge, on behalf of my Chief, Rear Admiral H. G. Bowen, the Newcomen Medal awarded the Admiral for his outstanding contribution to the better utilization of the power in steam.

I, personally, am glad to deputize in this matter for several reasons, the first of which is that it enables me to perform a small service for a Commanding Officer for whom I have the greatest respect and affection. Second, because Admiral Bowen has often talked to me of his experiences and early struggles to secure recognition for that which he believed to be so important. If ever there existed another case of where (to quote Churchill) "so many owed so much to so few," this is one, and the thanks and appreciation of the whole civilized world and particularly the U.S.A. are due to an officer who, in the face of almost universal difficulty, had the intestinal fortitude to persist in that which he believed in. Today, the steam-driven units of the U. S. Fleet equipped with high pressure, high temperature steam move from one location to another on one-third less oil consumption than those of equivalent type and size of other up-to-date navies. Furthermore, this same remarkable economy is obtained even when the ships are tied up and only the auxiliaries are operating.

If the foregoing contribution were the only one made by this far-seeing, courageous officer, it might be judged enough. However, his record includes other major developments which might easily be said to have had an equally major bearing on America's ability to wage a winning war.

You will be interested to know that all the improvements incident to the introduction of high pressure, high temperature have worked out most satisfactorily. The machinery has stood up well under the most severe conditions imaginable, namely—convoy duty off Iceland and combat action in the Tropics. It has shown itself particularly well

adaptable to operations by green crews. It became standard for surface combatant vessels beginning with 1938.

The design included integral superheat boilers with economizers but not air casings. It was distinguished also from earlier designs in that the cruising or high pressure turbine was directly coupled and always engaged. The main gears were the new double reduction type and a de-aerated feed water system was employed. This design represented the first time that efficient high speed turbines with double reduction gears and direct coupled cruising turbines had ever been installed in a Naval ship. These ships represented a complete American design in all respects.

The *Somers*, contracted for in 1934, designed by Gibbs & Cox, and built by Federal Shipbuilding and Dry Dock Company, had all of these innovations together with a steam condition of 600 pounds and 700 degrees Fahrenheit, as well as new superheat control boilers which also incorporated a double casing within which the air necessary to support combustion was confined. This is a definite military asset in case of gas attack. As finally built, the *Somers* was operated on a steam pressure of 600 pounds pressure and 850 degrees Fahrenheit, which is 369 degrees of superheat.

As a result of the success of the *Somers*, the Bureau of Engineering raised the steam pressure on the battleships *North Carolina* and *Washington*, building at the New York and Philadelphia Navy Yards, from 700 degrees Fahrenheit to 850 degrees Fahrenheit. They had already been designed for 600 pounds pressure.

Since the last war, the size, scope and influence of the American industrial research laboratories has increased by leaps and bounds. Gear cutting has become a highly specialized endeavor and the turbine companies, particularly the General Electric Company and Westinghouse Electric and Manufacturing Company, have poured millions of dollars into the development of steam turbines. Much attention to engine research also was given by Babcock & Wilcox, Foster Wheeler Corporation, and the De Laval Company.

In 1939, the four-stack destroyer, *U.S.S. Dahlgren*, was completely re-engined and re-boilered. This ship now uses steam at 1,300 pounds pressure and 925 degrees Fahrenheit in the main engines, which is reported to result in a still further improvement of ten per cent. in economy. While nothing has been done with this design in the past four years, it is understood that the Bureau of Ships will follow up this design in the near future, as the material situation permits.

This is the record to date. The future is what we make it—the possibilities are boundless and progress is only limited by the degree of hard work and application which we are prepared to invest. Unfortunately, we do not live forever—the task is that of the younger men, and I believe they are trained and able to carry it along to further successes.

Once more, on behalf of Admiral Bowen, permit me to express the deepest thanks and appreciation for this high honor which you have so perceptively bestowed on him.

MR. REDDING: Thank you, Commander Harrison.

Again, directly to you Admiral Bowen in your hospital bed in California, we extend our affectionate regards and our congratulations to you upon this honor—an award of high distinction in the field of Steam, by this 120-year-old internationally-known Institute.

And now, in concluding this quite unusual, and certainly interesting, transcontinental broadcast, each one of us here in Benjamin Franklin's presence, wishes you full recovery and "Godspeed"!

To The Senior Vice-President for North America in The Newcomen Society of England, who presides at these national Newcomen Dinners, I now turn back this meeting.

Ladies and Gentlemen, Dr. Penrose now will continue to preside.

* * *

Dr. Penrose then continued the activities of the Newcomen Society and called upon Dr. Henry Butler Allen, Secretary and Director of The Franklin Institute, to introduce the speaker of the evening, Dr. Carl Van Doren.†

After Dr. Van Doren's interesting paper, the meeting adjourned.

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, February 9, 1944.)

HALL OF THE COMMITTEE,
PHILADELPHIA, FEBRUARY 9, 1944.

MR. WILLIAM B. COLEMAN *in the Chair.*

The following report was presented for final action:

No. 3086: Reperforator Switching System.

This report recommended the award of the Certificate of Merit to The Western Union Telegraph Company, of New York, New York, "For the development of the Reperforator Switching System, a contribution to the greater accuracy and speed of telegraphic service."

JOHN FRAZER,
Secretary to Committee.

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† Dr. Van Doren's paper will be published in full by the Newcomen Society of North America.

LIBRARY NOTES.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thrity-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays from two until ten o'clock P.M.

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Bulletin Almanac and Year Book. 1944.

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MARSHALL, ROY K. Teachers' Manual of Elementary Astronomy. 1944.

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BOOTH, HAROLD SIMMONS, AND VIVIAN RICHARD DAMERELL. Quantitative Analysis. Second Edition. 1944.

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NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Effects of Various Chemicals on *Paramecium caudatum*.—HUGH E. POTTS. The effects on paramecium of a series of organic arsenicals (JOURNAL OF THE FRANKLIN INSTITUTE, **236**: 499, 1943) and of propionic acid and its sodium salt (JOURNAL OF THE FRANKLIN INSTITUTE, **236**: 99, 1943) have been reported.

The present paper deals with the effects on paramecium of various chemicals which do not constitute a single group of related compounds. Several of the compounds were synthesized by members of the Laboratory staff, Nos. 4 and 5 as new syntheses (*Journal of the American Chemical Society*, **62**: 3508, 1940) and Nos. 1, 2, 3, 20, 21, 22, 23, by standard procedures.

The method used in testing the substances was the same as that previously described with the exception that the number of paramecia was kept as nearly constant as possible. Eight drops of paramecium culture were placed in each of five watch glasses, the fifth being used as a control. To these, 8, 4, 2, 1 and 0 drops, respectively, of a given drug solution were added. The total number of drops in each glass was made up to 16, by adding a sufficient number of drops of filtered, boiled and cooled water taken from cultures of paramecium. Each compound was neutralized to approximately pH 7.0 prior to testing. The results are shown in Table I.

Benzenestibonic acid appeared to be more active than the pentavalent benzene arsenicals (JOURNAL OF THE FRANKLIN INSTITUTE, **236**: 499, 1943). Tartar emetic showed about the same order of activity as benzenestibonic acid.

Sulfanilamide was conspicuously ineffective. It might be that this type of drug would have some effect on the ability of paramecia to reproduce, but this has not been tested as yet, since inhibition of reproduction in cultures with bacteria present would not indicate whether the action was on paramecia or on their food supply.

The action of quinine plus urea HCl U.S.P. XI, which killed paramecium in 1 : 25,000, is fairly close to that of quinine alone on paramecium as shown by Feiler (*Archiv für Protistenkunde*, **59**: 562, 1927) where 1 : 100,000 was fatal. The action of sulfanilamide on paramecium, killing in 1 : 200, is of the same general order as shown by Ferguson *et al.* (*Journal of the Elisha Mitchell Scientific Society*, **58**: 53, 1942) on certain free-living protozoa.

Phenylmercuric acetate and phenylmercuric nitrate were exceedingly active against paramecia, as were also 8-hydroxyquinoline, diethyl-

TABLE I.

Effect of Various Chemicals on Paramecia.

No. of Chemical.	Name of Chemical.	Concentrations Tested.	Effect on *Paramecium caudatum*.
1	3-Pyridinesulfonic acid	1 : 126 1 : 629	Killed all in 30 min. Killed many in 30 min. but failed to kill all in 24 hrs.
2	Potassium-5-nitro-2-pyridinesulfonate	1 : 83 1 : 413	Killed all in 30 min. Killed many but not all in 24 hrs.
3	5-Amino-2-pyridine-sulfonic acid	1 : 230 1 : 575	Killed all in 24 hrs. Failed to kill any in 24 hrs.
4	5-Nitro-2-pyridyl phenyl sulfone	sat'd soln. (less than 1 : 1,000)	Killed all in 3 hrs.
5	5-Amino-2-pyridyl phenyl sulfone	sat'd soln. (less than 1 : 1,000)	Failed to kill any in 24 hrs.
6	Benzenestibonic acid	<1 : 743 <1 : 929	Killed all in 24 hrs. Killed a few but not all in 24 hrs.
7	Berberine	1 : 10,000 1 : 20,000 1 : 40,000	Killed all in 2 hrs. Killed all in 24 hrs. Failed to kill any in 24 hrs.
8	8-Hydroxyquinoline	1 : 1,000,000 1 : 2,000,000	Killed all in 1 to 2½ hrs. (2 tests) Killed all in 1 hr. (2 tests) (no greater dilution tested)
9	Phenylmercuric nitrate	1 : 1,600,000 1 : 3,200,000	Killed all in 24 hrs. Killed a few but not all in 24 hrs.
10	Phenylmercuric acetate	1 : 1,600,000 1 : 3,200,000	Killed all in 3 hrs. Killed all in 24 hrs. (no greater dilution tested)
11	Tartar emetic	1 : 400 1 : 800	Killed all in 5 to 24 hrs. (2 tests) Killed more than ½ but not all in 24 hrs.
12	Sulfanilamide	1 : 200 1 : 400	Killed all in 24 hrs. Killed more than ½ but not all in 24 hrs.
13	Acridone	1 : 500	Failed to kill any in 24 hrs.
14	Atebrine	1 : 51,200 1 : 102,400 1 : 204,800	Killed all in 6 hrs. Killed all in 24 hrs. Killed a few but not all in 24 hrs.
15	Rhodamine B	1 : 20,000 1 : 40,000	Killed all in 6 hrs. Killed a few but not all in 24 hrs.
16	Rhodamine G.D.N.	1 : 160,000 1 : 320,000	Killed all in 24 hrs. Killed most but not all in 24 hrs.
17	Fluorescein	1 : 200	Killed most but not all in 24 hrs.
18	Quinine+urea HCl U.S.P. XI	1 : 12,800 1 : 25,600	Killed all in 6 hrs. Killed most but not all in 24 hrs.

TABLE I (*Cont'd*).

No. of Chemical.	Name of Chemical.	Concentrations Tested.	Effect on *Paramecium caudatum*.
19	Contramine (B.D.H.) (Diethylammonium diethyldithiocarbamate)	1 : 25,600 1 : 51,200 1 : 25,600	Killed all in 6 to 24 hrs. (2 tests) Killed all in 24 hrs. Failed to kill any in 24 hrs. (solution had been left standing at room temperature for several days)
20	Diethylammonium benzyldithiocarbamate	1 : 1,024,000 1 : 2,048,000	Killed all in 24 hrs. Killed most but not all in 24 hrs.
21	Ammonium phenyl-dithiocarbamate	1 : 16,000	Killed all in 3 hrs.
21A	Ammonium phenyl-dithiocarbamate	1 : 32,000 1 : 64,000	Killed all in 4 hrs. Killed all in 4 hrs. Note: This compound was left for 24 hrs. in refrigerator prior to 2nd test, and appeared to be in process of decomposition.
22	Benzylammonium benzyldithiocarbamate	1 : 512,000 1 : 1,024,000	Killed all in 24 hrs. Killed a few but not all in 24 hrs.
23	*p*-Chlorophenylammonium *p*-chlorophenyldithiocarbamate	1 : 256,000	Killed only a very few in 24 hrs. (no greater concentration tested)

ammonium benzyldithiocarbamate and benzylammonium benzyldithiocarbamate.

A noticeable weakness in the use of an organism such as paramecium to detect substances which might be of therapeutic value in the treatment of protozoal or other diseases is that such substances as sulfanilamide would be entirely overlooked should the drugs be chosen only on the basis of killing action in great dilution. It is planned to culture paramecia bacteria-free and test for inhibition of reproduction as well as killing action of the drugs, thus taking into consideration two types of activity shown by drugs.

Summary and Conclusion: A number of related and some unrelated compounds were tested for their effects on paramecium. The most active were phenylmercuric acetate, phenylmercuric nitrate, 8-hydroxyquinoline, diethylammonium benzyldithiocarbamate and benzylammonium benzyldithiocarbamate. Sulfanilamide was one of the most inactive substances.

Of the recognized drugs tested it is seen that quinine, atebrine, 8-hydroxyquinoline, contramine and possibly berberine would have been singled out for possible therapeutic use on the basis of their high activity. The germicides, phenylmercuric nitrate and phenylmercuric acetate, would also have been singled out. Such an effective drug, however, as sulfanilamide would have been entirely disregarded. It is possible that

sulfanilamide and drugs that have similar action may have an inhibitory action on reproduction of protozoa as they do on bacteria. Plans have been made to test such drugs on bacteria-free paramecia in order that the effects may be judged both on the basis of killing action and on inhibition of reproduction.

Abstract of **The Adaptation of Magnetic Support to Air-Driven Ultracentrifuges.**—THOMAS J. DIETZ AND TERREL V. KISHBAUGH (JOURNAL OF THE FRANKLIN INSTITUTE, **236**: 445, 1943). Air-driven ultracentrifuges usually employ air support for the rotor, while those driven electrically use magnetic support. By adapting the magnetic support to the air-driven pattern, it is possible to secure the best features of each type while avoiding some of the disadvantages inherent in each.

The use of air drive obviates the necessity of cooling the driving motor, while the magnetic support avoids the vibration sometimes found in the air-supported type. There is an additional advantage in favor of the magnetic support in that the stray flux provides a magnetic field for the speed indicating device. Furthermore, because of inherent constructional features, the magnetic support is superior, since there is less danger of breakage of the shaft in case of support failure.

The magnetic support consists essentially of a solenoid with its armature mounted on the main shaft of the centrifuge. The armature is contained between the two bearings. The current in the solenoid may be adjusted to support nearly all the weight of the rotor, leaving a slight residual thrust against the lower bearing. An alternate method increases the solenoid current until the rotating system is lifted bodily and held with a slight force against the upper bearing.

Abstract of **A Recording and Controlling System for Air-Driven Ultracentrifuges.**—THOMAS J. DIETZ (JOURNAL OF THE FRANKLIN INTITUTE, **236**: 451, 1943). The operation of ultracentrifuges is considerably simplified by the addition of speed recording and controlling equipment. It is not generally realized, however, that such devices can be readily assembled from standard parts commercially available. An installation at the Biochemical Research Foundation, constructed in this way, offers many new features.

The principle of the method is one in common use, whereby the rotational speed is measured by determining the frequency of an alternating current generated in a pick-up coil by a single pole armature, attached to the rotating shaft and magnetized by stray flux from the supporting solenoid. The output of the pick-up coil is fed to an electronic frequency meter made by the General Radio Co. This provides continuous indication of the speed on its main dial, and also supplies actuating current for the Bristol Pyromaster which is the heart of the recording and controlling system.

The Pyromaster controls the driving air supply by regulating the pressure on a pilot airline, which, in turn, controls the opening of a diaphragm valve in the main line. The main driving air system is divided into two separate airlines, a high pressure section for accelerating and a low pressure section for maintaining constant speed. There is a safety feature inherent in this design, for once the centrifuge is placed on the automatic control system, it is supplied only by the low pressure line, and the total pressure there available is not sufficient to accelerate it to dangerous speeds even should the controlling mechanism fail to function.

BOOK REVIEWS.

LUBRICATION OF INDUSTRIAL AND MARINE MACHINERY, by William G. Forbes. 349 pages, 14 × 22 cms., illustrations. New York, John Wiley & Sons, Inc., 1943. Price $3.50.

The present high industrial activity has brought forth a demand for knowledge in specialized fields by those of some technical skill generally and not particularly along lines of the specialization. To meet this demand, a background of textbooks of the more practical type for various grades of technical education has been appearing. These include introductions to various fields of endeavor, for those now closely associated with new work as well as for those who hope to become associated with it. One of the subjects is lubrication and the book at hand falls into the class for those whose business it is at present to lubricate efficiently and maintain lubrication of industrial or marine machinery.

Lubrication is a broad subject and somewhat controversial mainly from the theoretical standpoint. At the present time, from a practical standpoint it is important to know those things which are necessary to solve lubrication problems first, in order to keep the wheels in motion. Much of the higher theory therefore can be dispensed with. The author of this book has undertaken the descriptions of current lubrication practices with this in mind. The book will be understood best by those with only some prerequisites in physics and chemistry. This is more apparent in the earlier parts where the fundamentals of petroleum distillation, cracking, refining and chemistry are taken up which are very helpful in understanding the latter part of the book. Together with these subjects on preparation is a chapter on tests and specifications, which for lubricating oils is of special importance. The number of tests which may be carried out has led to confusion in the minds of many, and occasionally lubricants are purchased by submitting specifications which have no practical value.

Leading from these somewhat basic subjects the book discusses the effect of heat and pressure on lubricating oils and the effect of metals on the oils. Bearing lubrication is next taken up. Here the mechanics of lubrication is discussed pointing out that no satisfactory explanation has been found for the peculiar property which imparts "oiliness" or "lubricity" to lubricating oils. The subject of bearings is divided into two general types, the first involving sliding and the second involving the separation of moving surfaces by balls or rollers. Later, methods for applying lubricants are covered and these are referred to in succeeding chapters on steam engines, turbines, pumps and compressors, refrigeration, gasoline and diesel engines, gears, machine tools, etc. In each of these the various aspects of lubrication are discussed and explained.

The latter part of the book is devoted to lubrication in a few selected industries and some of the associated specialized applications and problems. The industries are seen to be those where a wide variety of oils and greases are used. They include steel mills, paper mill and textile machinery, and subjects taken up separately include heat treating oils, wire ropes and cables, hot oil circulating systems, white oils, oil purification and reclaiming.

The nature of the book is primarily explanatory. Its greatest use is for operating men in industry who need clearer conceptions of the lubricating process. Those having to do with the business end of operating industry, such as purchasing agents, will find it helpful. And of course, those who contemplate being faced with lubrication problems will find here an understandable explanation. For all it is a good reference work.

R. H. OPPERMANN.

A SHORT COURSE IN QUANTITATIVE ANALYSIS, by H. H. Willard, Howell Furman and John F. Flagg. 253 pages, tables and diagrams, 14 × 22 cms. New York, D. Van Nostrand Co., Inc., 1943. Price $2.50.

The importance of quantitative chemical analysis in numerous branches of pure and applied chemistry is plainly evident by the fact that a large demand exists today for training

at an elementary level from students of many fields of endeavor. It is a subject which serves as a background for more specialized study in the particular field of interest. This book was written with these facts in mind. It covers only what is necessary or reasonable for a one-semester course and this has been attained by simplification and elimination from the work "Elementary Quantitative Analysis" by Willard and Furman.

The book is generally designed as an introduction to the theory and to certain types of manipulation. Under the theory part there is treated the law of mass action (chemical equilibrium) and variables which affect equilibria. Laboratory work is discussed including general operations such as filtration and washing, drying and heating. After this, methods of measurements are taken up, all of which leads up to a discussion of the general principles of volumetric analysis. The theory of acidimetry and alkalimetry precedes a section on procedures, and like method of treatment is applied to volumetric precipitations, oxidations and reductions and gravimetric analysis. A number of appendixes give helpful information in the form of a bibliography and several tables of data. At the end there is a subject index for reference work. It will be seen that the order of presentation of the topics is similar to "Elementary Quantitative Analysis."

The course presented is thorough and rigorous. At the ends of chapters are problems for exercise, the answers to which are given. The procedures described are clear and little difficulty should be encountered in following them. The book is good for a brief elementary course from many standpoints including teaching merits, flexibility and practical value.

R. H. OPPERMANN.

THE SCIENCE OF EXPLOSIVES, AN INTRODUCTION TO THEIR CHEMISTRY, PRODUCTION AND ANALYSIS, by Martin Meyer. 452 pages, illustrations, 15 × 22 cms. New York, Thomas Y. Crowell Co., 1943. Price $4.50.

Explosives enter into modern life on a very large scale. This applies to peace time as well as war time. As a matter of fact, explosives undoubtedly rank with the greatest discoveries man has ever made. A first class nation at peace may annually use as much as 300,000 tons and it may safely be said that without explosives modern engineering achievements would be infinitely more difficult, if not impossible. Of course, explosives are notoriously applied to war. The annual use in war time of a first class nation may rise to 3,000,000 tons or more. This important industry has been accompanied by a mass of excellent literature, but possibly because of its peace-time specialization, there is an absence of literature in book form written in the more generally understandable style. At present a larger number of people are interested in explosives and they bring a demand for such literature. The book at hand is just such a work.

It opens a general survey of the explosives industry. In it there is a touch of history, statistics on manufacture, chemistry, laboratory work, and the storage and handling of explosives. The reader is then taken into a discussion of the nature of explosives, the chemical changes which take place, the heat of explosion, velocity, mechanism, etc. As an elementary consideration for all propellent explosives considerable space is devoted to black powder, and this is followed by treatments on nitrocellulose and other nitropolysaccharides, and nitroglycerine and related explosives. In this coverage a number of the characteristics of explosives are mentioned which leads to the treatment on the elementary theory of explosive action. From here the progression is through the various factors and processes important in the manufacture and quality of explosives. Included are grain size, the problem of nitration, nitric acid, sulphuric acid. Smokeless powder is given adequate attention as is T.N.T. and other explosives, including gases.

What may be taken as a separate part of the book is that devoted to the chemistry of initiators and explosive devices covering the more important general characteristics without entering into a discussion of very specific details. The latter part of the book discusses methods of inspection and analysis, the application and use of explosives and the packing, shipping, storage and safety of explosives. At the end there are a bibliography of publications from the 16th century onward, a number of useful tables, and a subject index.

At the end of each chapter there are a number of questions and exercises. Throughout there are tables, diagrams, and curves wherever necessary to facilitate understanding. The subject is presented from the standpoint of the chemist, although by no means is it exclusively a chemical publication. The book follows a logical progression and should be of value to those interested in the manufacture and use of explosives.

R. H. OPPERMANN.

ELASTIC AND CREEP PROPERTIES OF FILAMENTOUS MATERIALS AND OTHER HIGH POLYMERS, by Herbert Leaderman. 278 pages, illustrations, 18 × 26 cms. Washington, D. C., The Textile Foundation, 1943. Price $2.00.

The rapid development of man-made fibers brought forth the demand for knowledge of certain properties of them. That this demand was almost as important as the fibers themselves can be realized when it is brought to mind that many uses of the material are dependent upon these properties. And today it is a fact that the important role played by synthetic high polymeric materials in the war effort and elsewhere is due in a large measure to a knowledge of certain of their valuable properties.

This book gives the results of an investigation on the elastic and creep properties of filamentous materials carried out at the Massachusetts Institute of Technology under the auspices of The Textile Foundation. The author has made an exhaustive search and evaluation of literature on textile research since the beginning of the 19th century. A list of the references is given in the back of the book and many are cited in the text.

The book consists of two parts. The first discusses the phenomenon of delayed elasticity (or "primary creep"), together with the relationship between the phenomenon and the structure of high polymers. Chapter I is concerned with the delayed elastic behavior of materials in the light of some historically important work presented in the literature. Next the mechanical model analogy is developed in relation to the theories of Maxwell and Wiechert which is followed by a presentation of the contemporary concepts of structure. All of this forms an introduction to the second part which gives an account of experiments on the creep and creep recovery behavior of rayon, nylon and silk filaments. The experimental results are interpreted in terms of the structure of these materials, and conclusions are drawn concerning the mechanism of elastic and plastic deformation of textile filaments.

The work is well illustrated and at the end there is a comprehensive subject index. There is much here in current concepts concerning the structure and mechanical behavior which should have wide appeal, particularly in the textile industry, and in the manufacture and processing of plastics and rubber-like materials.

R. H. OPPERMANN.

BASIC AIRCRAFT CONSTRUCTION, by Ross A. Peterson and Raymond E. Erickson. 204 pages, illustrations and diagrams, 13 × 19 cms. New York, Prentice-Hall, Inc., 1943. Price $2.00.

Only a short time ago, aircraft manufacturing was a peace-time activity catering to a growing peace-time industry. That there was a bright future for it, no one doubted. Then there was some demand for skilled artisans, which was quickly filled as it appeared. Today this industry has risen to become a giant, a high speed mass-production process, using much of the available skill and resources of the nation. The demand for skilled artisans is great and not quickly filled. With the thought of improving the aircraft worker to do better work and become of greater value to the industry, and to help satisfy the demand, this book is written. Its style is simple and its coverage is practical.

The reader is introduced to the parts of an airplane and the terms and functions of the parts are explained. The methods of aircraft production are laid out to give an over-all picture; then the various stages of manufacture are taken up. First there is the blue print which is followed by the work of the tooling department. Then a discussion on materials and substitutes used in aircraft production precedes a treatment on the fundamentals common to all phases of machine

shop work. Sheet metal preparation and fabrication is a very informative section of the book. And finally an outline of the fundamentals and techniques of riveting is given.

An appendix contains a fund of useful information including definitions of common aircraft terms. In the back is a subject index.

The book is practical, easy to understand, and should fit into the situation of many aircraft workers, men and women alike, in the widely different places in the aircraft industry.

R. H. OPPERMANN.

THE AMERICAN ANNUAL OF PHOTOGRAPHY. Volume 58, 1944. 206 pages, illustrations, 18 × 25 cms. Boston, American Photographic Publishing Co., 1943. Price $1.50, paper.

The year 1943 has been so embodied by the war effort that, at first thought, there would seem to be little left for other things. A glance at the *American Annual of Photography*, Volume 58, would quickly dispel this, for it looks as large and just as full of interesting material as its predecessors. There are a number of articles that are of general interest, others of value to the photographer alone, and of course the illustrations are stories of many kinds in themselves. An unusual definition of art and photographic technique is given at the outset in the article "A Personal Credo, 1943" by Ansel Adams. The author separates the subject and examines each parcel minutely in an interesting and easy-to-read manner. Then there is the description of a new bromoil technique by E. Lind wherein the theory of porosity is made the basis. Other works by other authors deal with photography and natural history, flower photography, electronic high speed photo light, etc. The pictorial illustrations are of wide variety. In the back there is the list of Who's Who in Pictorial Photography as in other editions of the Annual. Then there is the technical data which includes the American Annual Formulary with its broad coverage. The *Annual* as usual is a worthwhile addition to the books of amateurs and professionals alike.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

So You Want to Be a Chemist, by Herbert Coith. 128 pages, 13 × 19 cms. New York, McGraw-Hill Book Company, 1943.

Principles and Applications of Electrochemistry, Volume II, Second Edition, by W. A. Koehler. 573 pages, drawings and photographs, 14 × 22 cms. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1944. Price $5.00.

Quantum Chemistry, by Henry Eyring, John Walter and George E. Kimball. 394 pages, illustrations, 14 × 22 cms. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1944. Price $5.00.

Electron-Optics, by Paul Hatschek, Translated by Arthur Palme. 161 pages, drawings and photographs, 16 × 24 cms. Boston, Mass., American Photographic Publishing Co., 1944. Price $3.00.

Table of Circular and Hyperbolic Tangents and Cotangents for Radian Arguments, prepared by the Mathematical Tables Project, Work Projects Administration of the Federal Works Agency, conducted under the Sponsorship of the National Bureau of Standards. 410 pages, 20 × 27 cms. New York, Columbia University Press, 1943. Price $5.00.

Table of Reciprocals of the Integers from 100,000 through 200,009, prepared by the Mathematical Tables Project, Work Projects Administration of the Federal Works Agency, conducted under the Sponsorship of the National Bureau of Standards. 201 pages, 20 × 27 cms. New York, Columbia University Press, 1943. Price $4.00.

The Table of the Bessel Functions $J_0(Z)$ and $J_1(Z)$ for Complex Arguments, prepared by the Mathematical Tables Project, Work Projects Administration of the Federal Works Agency, conducted under the Sponsorship of the National Bureau of Standards. 403 pages, 20 × 27 cms. New York, Columbia University Press, 1943. Price $5.00.

Basic Mathematics for War and Industry by Paul H. Daus, John M. Gleason and William M. Whyburn. 277 pages, tables and illustrations, 15 × 22 cms. New York, The Macmillan Company, 1944. Price $2.00.

Dynamical Analogies by Harry F. Olson. 196 pages, illustrations, 14 × 22 cms. New York, D. Van Nostrand Company, Inc., 1943.

Communication Circuits, Second Edition, by Lawrence A. Ware and Henry R. Reed. 330 pages, illustrations, 14 × 22 cms. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, 1944. Price $3.50.

CURRENT TOPICS.

THE AMERICAN PATENT SYSTEM.*

REPORT of the NATIONAL PATENT PLANNING COMMISSION.

Chairman: Charles F. Kettering; *Members:* Chester C. Davis, Francis P. Gaines, Edward F. F. McGrady, Owen D. Young; *Executive Director,* Andrey A. Potter; *Executive Secretary,* Conway P. Coe.

EXECUTIVE ORDER ESTABLISHING THE NATIONAL PATENT PLANNING COMMISSION.

WHEREAS both American industrial development and our people generally have greatly benefited by the products of American inventive genius;

AND WHEREAS it is essential even in time of war to plan for a full utilization of the nation's expanded industrial capacity with the return of peace, a problem to which the inventive genius of our citizens can be applied at this time and which also requires a study to be made of our existing patent laws and procedure, together with other appropriate action, by a commission familiar with the problems of science, industry, agriculture, labor, and the consumer;

NOW, THEREFORE, by virtue of the authority vested in me as President of the United States, I do hereby order as follows:

1. There is hereby established the National Patent Planning Commission consisting of five members to be appointed by the President.

2. The Commission is authorized, in conjunction with the Department of Commerce, to conduct a comprehensive survey and study of the American patent system, and consider whether the system now provides the maximum service in stimulating the inventive genius of our people in evolving inventions and in furthering their prompt utilization for the public good; whether our patent system should perform a more active function in inventive development; whether there are obstructions in our existing system of patent laws, and if so, how they can be eliminated; to what extent the Government should go in stimulating inventive effort in normal times; and what methods and plans might be developed to promote inventions and discoveries which will increase commerce, provide employment, and fully utilize expanded defense industrial facilities during normal times.

3. The Commission may appoint such officers, committees and subcommittees as it may deem necessary to carry out its functions.

4. The members of the Commission and of such committees and subcommittees as may be formed by it shall serve as such without compensation but shall be entitled to actual and necessary transportation, subsistence, and other expenses incidental to the performance of their duties.

5. The Commissioner of Patents and his office will assist the Commission, which is also authorized to call upon other offices and agencies of the Government for such aid and information as may be deemed necessary for its work.

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* Patent, Trade Mark and Copyright Weekly Reports. **Vol. 57, No. 12—Special Edition, June 19, 1943**

6. The Commission shall report the results of such investigations and studies to the President, together with its recommendations.

The White House, FRANKLIN D. ROOSEVELT
December 12, 1941.

(No. 8977)

(F.R. Doc. 41-9471; Filed, December 16, 1941; 12:04 p.m.)
(From FEDERAL REGISTER, Wed., Dec. 17, 1941; Vol. 6, No. 244)

I. INTRODUCTION.

In accordance with Executive Order No. 8977 of December 12, 1941, the National Patent Planning Commission has been engaged in a study of the American patent system and its operation.

The American patent system established by the Constitution giving Congress the "power to promote the progress of science and useful arts," is over 150 years old. The system has accomplished all that the framers of the Constitution intended. It is the only provision of the government for the promotion of invention and discovery and is the basis upon which our entire industrial civilization rests.

The American people and their government should recognize the fundamental rightness and fairness of protecting the creations of its inventors by the patent grant. The basic principles of the present system should be preserved. The system has contributed to the growth and greatness of our nation: it has:

(1) encouraged and rewarded inventiveness and creativeness, producing new products and processes which have placed the United States far ahead of other countries in the field of scientific and technological endeavor;
(2) stimulated American inventors to originate a major portion of the important industrial and basic inventions of the past 150 years;
(3) facilitated the rapid development and general application of new discoveries in the United States to an extent exceeding that of any other country;
(4) contributed to the achievement of the highest standard of living that any nation has ever enjoyed;
(5) stimulated creation and development of products and processes necessary to arm the nation and to wage successful war;
(6) contributed to the improvement of the public health and the public safety; and
(7) operated to protect the individual and small business concerns during the formative period of a new enterprise.

The strongest industrial nations have the most effective patent systems and, after a careful study, the Commission has reached the conclusion that the American system is the best in the world. However, as with any system of long standing, conditions arise which were not foreseen at the time of its establishment. The American patent system should be adjusted to meet existing conditions without destroying its basic principles.

II. PATENTS AND THE WAR EFFORT.

Specific inquiries addressed particularly to representatives of the War and Navy Departments failed to develop any serious instances in which the patent system has interfered with the prosecution of the present war. The outcome of this war, more than any previous war, will depend upon continuous superiority in science and invention. Never before has there been such a free exchange of scientific and technological knowledge and products of invention between our industrial concerns, our research laboratories and our own government, and between our government and our allies. Such a liberal and complete exchange of scientific information and the secrets of industrial laboratories could not have been possible without the reassurance of the protection afforded by the patent system. The American people should recognize the part the system is thus playing in the free exchange of scientific information which is proving so effective in the prosecution of the war and which is so essential to ultimate victory.

Existing laws permit the government of the United States and its contractors and sub-contractors to manufacture and use any invention, patented or unpatented, regardless of the citizenship of the owner, upon the payment of reasonable compensation. These laws operate both in peace and in war. After consulting with the several government departments, including the War and the Navy, and affording them an opportunity for the presentation of evidence, the Commission is convinced that the existing laws are adequate to protect the government during the present national crisis.

III. PROTECTION OF THE PUBLIC INTEREST.

A. Recording of Contracts.

The chief beneficiary of our patent system should be the American public. This is true whether a patented invention is commercialized or not. In the former case, the public has for its use and at its disposal a new product or process; in the latter it has made available recorded knowledge which prior to the effort of the inventor was unknown to the world. Despite these benefits to the general public from the operation of the patent system it is nevertheless true that patents may be and have been abused. The abuse arises not from the patent itself but by virtue of secret, improper, and even illegal agreements. The exposure of agreements dealing with patents should minimize these abuses and, in any event, make them readily detectable. The Commission accordingly feels that there should be a compulsory requirement for the recording of the agreements so that they will be available to the public, to governmental agencies, and to Congressional committees.

The Commission therefore recommends the passage of legislation compelling the recording in the United States Patent Office of:

(1) *all existing agreements to which one of the parties is a citizen of a country foreign to the United States;*

(2) *all existing agreements regardless of citizenship of the parties which include any restrictions as to price, quantity of production, geographical areas or fields of use;*

(3) *all future agreements regardless of restrictions or citizenship of the parties.*

B. (1) Compulsory Licensing—Patents Affecting National Defense, Public Health and Public Safety.

After a study of the needs in this country and the effects in foreign countries of a compulsory licensing system, the Commission has reached the conclusion that it would not be advantageous to incorporate such a general system in our patent laws. However, the Commission is impressed with the need of a degree of compulsion in certain fields, such as national defense, public health, and public safety. While the Commission is unaware of any case in which a court has prohibited the use of an invention covered by a patent when the effect of such prohibition would be injurious to national defense, public health or public safety, nevertheless it is felt that the statutory laws should be so clarified as to remove any possible doubt on the subject.

The Commission therefore recommends a statutory provision that in a suit for infringement the recovery of a patent owner shall be limited to reasonable compensation without prohibiting the use of the patented invention whenever the court finds that the particular use of the invention in controversy is necessary to the national defense or required by the public health or public safety.

B. (2) Ruling Before Suit on Patents Affecting National Defense, Public Health and Public Safety.

The Commission is also impressed with the desirability of establishing a procedure whereby the question whether a particular use in competent hands of a patented invention falls within the field of national defense, public health or public safety can be determined in advance of litigation.

It therefore further recommends that the Commissioner of Patents be authorized to entertain and decide the question initially upon request of one of the interested parties prior to the institution of suit, the decision of the Commissioner to be subject to review by the United States Court of Customs and Patent Appeals.

C. Revocation of Patent Grant.

It is generally conceded that the United States Patent Office has a more thorough and highly developed procedure for the examination of applications for patent than any other country. However, in spite of the efficiency of its classification system and examining technique it is obvious that the examiners are not and cannot be informed as to all existing facts having a bearing upon the novelty or prior use of the thousands of inventions deposited in the office each year. It follows that a patent may be and frequently is granted which would have been refused if the Patent Office had been in possession of additional facts. No opportunity is afforded the public for submitting evidence to the Patent Office or supplying pertinent facts as to novelty and use prior to the issuance of a patent. An issued patent is invalid if the patentee was not the first and original inventor or if the invention was published and publicly used for a certain period before the application was filed. Yet although a patent may be invalid or of questionable validity for any of the foregoing reasons, it may be used by the owner as an instrument in restraint of trade or to force tribute from unwilling licensees or be used in various other known ways to accomplish many of the purposes that would be legitimate only under a valid patent. Even the Patent Office itself is powerless to withdraw or to cancel an issued patent however inadvertently granted. This unhealthy situation constitutes one of the serious weaknesses in the present system.

There should be some provision whereby information and facts bearing

upon the validity of a patent can be brought to the Patent Office thereby giving it an opportunity to reexamine its decision to grant a patent and also to afford the public a full opportunity to challenge the validity and to bring about a revocation of an improperly granted patent.

The Commission recommends that opportunity be accorded any member of the public to challenge the validity of any patent in a proceeding begun within six months after its grant. The enabling legislation should specify that the failure to challenge within the period indicated shall not prejudice the rights of any person in a subsequent infringement suit. Cancellation proceedings should be initiated in the Patent Office with an appeal by either party to the Court of Customs and Patent Appeals. The services of an officer in the nature of a public defender should be made available to the patentee.

IV. EXTENDING THE USE OF PATENTS.

Public Register of Patents Available for Licensing.

A study of foreign patent systems and especially a feature of the British patent law commonly known as "licenses of right" has prompted the conclusion that it would be a desirable innovation in our own system to provide a mechanism whereby a patent owner can publicly proclaim his willingness to grant licenses under his patent on either stated or reasonable terms. This could be accomplished by providing a public register in the Patent Office on which such patents would be entered upon request of their owners together with a statement of terms, if any, on which a license will be granted. The entry of patents upon such a register should be published in the Official Gazette of the Patent Office and other appropriate publications. It is believed that both individual inventors who find it difficult to contact and interest manufacturers in the exploitation of their inventions and the owners of large aggregations of patents would welcome the opportunity of placing their patents on such an official government register. The recording of patents on the register should be at government expense without cost to the patentee. When the terms of the license are not stated, the Commissioner of Patents should be authorized to fix reasonable terms when the owner and prospective licensee cannot agree.

The Commission therefore recommends establishment in the Patent Office of a public register upon which would be placed those patents under which the owner would be willing to grant licenses on stated or reasonable terms. When an interested party and the owner are unable to agree as to the unstated terms for a license under a patent entered on the register the Commissioner of Patents shall fix the terms after an opportunity for hearing with right of appeal to the Court of Customs and Patent Appeals.

V. UNIFORM STANDARD OF INVENTION.

A. Declaration of National Policy.

The most serious weakness in the present patent system is the lack of a uniform test or standard for determining whether the particular contribution of an inventor merits the award of the patent grant. The patent statute itself is quite specific. R. S. 4886 provides that a patent may be obtained by "any person who has invented or discovered any new and useful art, machine, manufacture, or composition of matter, or any new and useful improvements thereof, . . . upon payment of the fees required by law and other due proceedings

had." The difficulty in applying this statute arises out of the presence of the words "invented" and "discovered." Novelty alone is not sufficient, nor is utility, nor is the final accomplishment. There must also be present some mysterious ingredient connoted in the term "invented."

Many different and unrelated tribunals now are forced to make their individual decisions, among them being the Patent Office, the several district courts, the various courts of appeals and the Supreme Court. The difficulty is that there is no accepted uniform standard among these several tribunals which can be applied in the same or similar cases. There is an ever widening gulf between the decisions of the Patent Office in granting patents and decisions of the courts who pass upon their validity. It would be highly desirable and a great step forward if patents could be issued with a greater assurance that their validity would be upheld by the courts. No other feature of our law is more destructive to the purpose of the patent system than this existing uncertainty as to the validity of a patent. The admonition is frequently heard that there should be "fewer and better patents," an impossible accomplishment so long as the present divergence of standards between the Patent Office and the courts and the several courts themselves obtains. Whether the standards of the Patent Office is too low or that of the courts is too high is not for us to determine. There should be a uniformity in the grant and treatment of patents. The present confusion threatens the usefulness of the whole patent system and calls for an immediate and effective remedy.

It is inconsistent with sound national policy to continue to grant patents with existing uncertainty as to their validity, and unfair to the inventors of this country and to manufacturers and inventors who have proceeded on the basis of a protective security in the form of a patent issued to them by the Federal Government. The Commission feels that not one but several steps should be taken to remedy the present situation. A promising improvement would be for Congress, by legislative enactment, to lay down a reasonable, understandable test by which inventions shall be judged both from the standpoint of the grant of the patent and the validity of the patent thereafter.

The Commission therefore recommends the enactment of a declaration of policy that patentability shall be determined objectively by the nature of the contribution to the advancement of the art, and not subjectively by the nature of the process by which the invention may have been accomplished.

B. Re-examination by the Patent Office of Validity Questions.

The provision of a definitive yardstick for determining the existence of an invention is not alone sufficient. There must also be some assurance of a uniform application of the yardstick. The validity of a patent is now passed upon initially by any one of almost a hundred district courts in the United States, by eleven different circuit courts of appeals and occasionally by the Supreme Court. The test of invention should be the same and uniform whether applied in the Patent Office or in any one of these courts. The only divergence in opinion should come from a divergence of facts. If, during the adjudication of a patent before a district court, new facts and evidence unknown to the Patent Office are submitted, the Patent Office should have an opportunity to revise its former opinion and to restate its conclusions on the basis of the additional information.

The Commission therefore recommends that whenever the validity of a patent is attacked in an infringement suit before a district court the court shall certify the record to the Patent Office for a report on the validity of the patent. The report of the Patent Office as to the effect of the court record upon the validity of the patent shall be advisory only.

C. Creation of a Court of Patent Appeals.

As a final step in remedying the chaotic and confusing conditions surrounding the grant and validity of patents the Commission considers it imperative to establish a single court of patent appeals which would receive and decide appeals from all of the district courts in patent cases, and whose decisions would be effective not only in a particular circuit but throughout the whole United States. This is not a novel suggestion. A single court of patent appeals was recommended by the Science Advisory Board, appointed by the President on July 31, 1933, has received the consideration and approval of a number of prominent manufacturing, engineering and legal associations, and was recommended in the final report of the Temporary National Economic Committee. It has also been favorably reported by the Senate Patent Committee after full public hearings.

The creation of an entirely new court is not necessary. The Commission notes that the Court of Customs and Patent Appeals has now become a seasoned tribunal whose judges are trained and experienced in patent law. With expanded jurisdiction and additional judges this court could function as a single patent court of appeals. Already possessed of appellate jurisdiction from the Patent Office this court, in its exercise of appellate jurisdiction from the several district courts, would tend still further to promote the adoption of uniform standards of patentability.

The Commission therefore recommends the establishment of a single court of patent appeals. It further recommends that the jurisdiction of the existing Court of Customs and Patent Appeals be expanded so as to function as such a court, that provision be made for the court to sit elsewhere than Washington, and that additional judges be temporarily assigned to the court by the Chief Justice of the United States in such numbers and for such times and at such places as the public interest may require.

VI. EARLY TERMINATION OF PATENT GRANT.

The term of a United States patent is seventeen years from the date of its grant. The expiration date of the patent is of special interest to the public since it is then that the subject matter of the patent passes into the public domain. It is most desirable, and in the public interest, that the patent should be issued as promptly as possible after the application is filed. There are numerous ways in which the prosecution of an application can be deliberately delayed and kept pending in the Patent Office for an indefinite time—and the expiration of the term of the patent thus correspondingly deferred. It is inevitable that opportunities for such delays will continue, and the best solution appears to be to encourage expeditious prosecution on the part of the applicants and their solicitors by penalizing an applicant who fails to prosecute his application diligently.

A proposal of long standing is that the patent monopoly shall not endure

more than twenty years from the date of its filing in the Patent Office. This is generally known as the Twenty Year Bill. A period of three years has been recognized as a reasonable period for prosecuting an application to allowance. There would be no change in the present seventeen year period of a patent in those cases in which the prosecution did not consume more than three years. Any delays beyond that period, however, would ordinarily subtract from the duration of the patent. Thus if an application were pending for five years the life of a patent would be reduced to fifteen years. It is recognized that it would be unfair to penalize some applicants by the operation of such a law because a case encountered unavoidable delays or even delays for which the Patent Office was wholly responsible. Therefore there should be some provision for the restoration by the Commissioner of Patents of not more than two years to the life of a patent when the delay has been due to causes beyond the control of the applicant.

The Commission therefore recommends the enactment of a Twenty Year Bill in substantially the same form as presented in H.R. 3211 to the 77th Congress.

VII. SIMPLIFICATION OF APPELLATE PROCEDURE.

When an application for patent is finally refused by the Patent Office existing laws provide relief to the inventor in the form of two alternative remedies. He has the option of either appealing to the Court of Customs and Patent Appeals, or filing a bill in equity for review in a United States District Court. In practice this latter option means that the inventor must proceed in the District Court of the United States for the District of Columbia because the District of Columbia is the only jurisdiction in which service can be obtained on the Commissioner of Patents.

The existence of these two parallel remedies is largely the result of historical accident, and does not appear to be justified or required by any fundamental considerations. The Commission is not impressed with the necessity for indefinitely perpetuating this anomalous situation, and it believes that one or the other of these alternatives should be discontinued.

From the standpoint of the litigants one of the principal advantages in electing to go to the District Court is that in practice it affords an opportunity to try *de novo* a case in which the applicant has not made a full or complete record in the Patent Office. This particular argument in support of that alternative does not appeal strongly to the Commission, especially where as here the case has already gone through the stage of an intermediate statutory appeal to the Board of Appeals. The Commission understands that the Patent Office procedure is liberal in giving a diligent applicant the fullest opportunity to present his case, but if the procedure is in any way inadequate in that respect the remedy should be applied at that point and not in the appellate stage.

As has been previously noted the Court of Customs and Patent Appeals has had wide experience in patent cases whereas this particular District Court is one of the busiest in the country and the time and attention which it can give to highly technical matters is necessarily limited. Furthermore the judges of the Court of Customs and Patent Appeals sit in banc, as is customary in appellate courts, and this practice is better adapted to the exercise of a reviewing function. In the District Court, however, only a single judge is available to hear any particular case, and over any given period the separate assignment of

various patent cases among twelve different judges whose experience in this particular field is necessarily subject to wide variation leads away from rather than toward that unification of standards so much to be desired.

The Commission recommends that in ex parte cases the jurisdiction of the Court of Customs and Patent Appeals to review the denials by the Patent Office of an application for patent should be made exclusive, and that the present concurrent jurisdiction of the district courts should be abolished. Sections 4911 and 4915 of the Revised Statutes should be amended accordingly.

VIII. INTERFERENCE PRACTICE.

In the course of the deliberations of the Commission numerous suggestions relating to changes in interference practice have been received. An interference is a procedure to determine which of rival claimants is the first inventor and therefore entitled to the patent. This procedure is unavoidable under the American practice according to which the patent can be granted only to the first inventor. A recent statutory change (Act of August 5, 1939) designed to simplify and expedite the course of an interference in the Patent Office has only begun to show its effect.

Additionally, certain recommendations made by the Commission herein, if adopted, will tend to reduce the number and causes of interferences. This result can well be expected from an application of the Twenty Year Bill and the provision for the revocation of patents.

For these reasons the Commission considers it inadvisable to recommend additional changes in the interference practice at the present time. It is expected, however, that this whole vital and important subject will be thoroughly reexplored by the Patent Office Advisory Committee in the light of the recommendations contained in this report.

IX. SCOPE OF INVESTIGATION.

The Commission has reviewed and considered various publications and compilations bearing upon the subject of its inquiry. Among these are:

(a) the records of various Congressional hearings.
(b) the reports of previous governmental commissions and investigating bodies.
(c) reports, where available, of investigations made by or on behalf of industrial organizations.
(d) numerous published papers and contemporaneous articles in trade journals, law journals and popular periodicals.

Suggestions from individuals and organizations were submitted to the Commission in written communications and at conferences arranged by invitation of the Commission. Proposals and suggestions in great volume were received from widely scattered sources such as

(a) representatives of government departments.
(b) manufacturers associations, scientific and engineering societies, bar associations and research institutes.
(c) individuals including lawyers, inventors, scientists, engineers and manufacturers.

X. SUBJECTS CONSIDERED WITHOUT RECOMMENDATION.

During the course of its investigation the Commission received and gave serious study to many suggestions and proposals for reforming the patent system which have not been made the subject of recommendation for one or more of the following reasons:

(1) The proposed reforms would not be a beneficial innovation in our patent system. Examples of such proposals are a broad compulsory licensing system, outlawing certain limitations in patent licenses, major and minor patents, patents for different terms of years, and opposition proceedings.

(2) Highly technical procedural reforms not involving any basic principle. In this category fall such subjects as interference procedure, disclaimer laws, the disclosure of patent specifications and the form of claims.

(3) Questions of internal practices and procedure within the Patent Office.

All suggestions falling in the last two classifications have been compiled and will be referred to the Patent Office Advisory Committee, appointed by the Secretary of Commerce in June 1933, for a more detailed study and proper disposition.

XI. SUMMARY OF FINDINGS AND RECOMMENDATIONS.

1. *The Patent System of the United States.*

The Patent System is the foundation of American enterprise and has demonstrated its value over a period coextensive with the life of our government. The principle of recognizing a property right in intellectual creation is sound and should be continued as contemplated in the Constitution.

2. *Patents and the War Effort.*

This involves no serious problem since under existing laws the government has the right to use any patented invention. Although full opportunity has been given, and specific inquiry made by the Commission of the armed services, no evidence has been submitted of specific instances of the use of patents to hamper the war effort.

3. *Protection of the Public Interest.*

The Commission believes the public interest can be further protected by several modifications in and additions to the patent laws. These changes will serve to prevent the abuse of the rights granted by patents while maintaining the fundamental principles of a tried and proven system.

To expose secret, improper or illegal agreements, it is proposed that all patent agreements be recorded with the United States Patent Office.

It is proposed that in a suit for infringement, a patent owner shall be limited to reasonable compensation without prohibiting the use of the patented invention whenever the court finds that manufacture of the invention is necessary to the national defense or required by the public health or public safety.

To invalidate patents which later information shows should not have been issued, a provision is proposed for cancellation of an issued patent.

4. *Extending the Use of Patents.*

It is recognized by the Commission that our system should afford a patent owner an opportunity of publicly declaring his willingness to grant licenses

under reasonable terms. A public register of such patents in the Patent Office is therefore proposed.

5. *Uniform Standard of Invention.*

One of the greatest technical weaknesses of the patent system is the lack of a definitive yardstick as to what is invention. To provide such a yardstick and to assure that the various courts of law and the Patent Office shall use the same standards, several changes are suggested. It is proposed that Congress shall declare a national standard whereby patentability of an invention shall be determined by the objective test as to its advancement of the arts and sciences. It is further proposed that when the validity of a patent is challenged in an infringement suit the court record shall be referred to the Patent Office for its opinion in the light of any new evidence or facts developed during the trial. Finally, it is proposed that a single court of patent appeals be established.

6. *Early Termination of Patent Grant.*

A patent application can be delayed and kept pending for undue and prolonged periods. This postponement of the beginning and ending of the patent term is not in the public interest. It is proposed that the patent term shall not endure more than twenty years after the application is filed. The present term of seventeen years would be retained except in those cases where more than three years were consumed in obtaining a patent. Delays of more than three years in the prosecution of an application for patent would result in a corresponding shortening of the seventeen year term.

7. *Simplification of Appellate Procedure.*

When a patent is refused by the Patent Office the inventor now has relief in the form of review by either of two courts. This is both confusing and unnecessary. It is proposed that the Court of Customs and Patent Appeals be designated as the sole reviewing body upon the denial of a patent by the Patent Office.

XII. FUTURE REPORTS.

The present report is confined generally to the mechanics of the patent law and the use of patents. The Commission is now engaged in a study of the policies involved in connection with inventions made by Government employees and by agents and contractors of the Government and with the control and use of patents owned by the Federal Government.

The Commission is also conducting a study in fulfillment of the final directive of the Executive Order, i.e., "what methods and plans might be developed to promote inventions and discoveries which will increase commerce, provide employment, and fully utilize expanded defense industrial facilities during normal times."

The results of these studies will be the subject of future reports.

ARMY AND NAVY NOTES.

Nebelwerfer 41.—WILLY LEY. (*Coast Artillery Journal*, Vol. LXXXVI, No. 4.) When the Red Army retook Veliki Luki the first specimens of a peculiar German weapon were captured and examined. This weapon, the existence of which was, of course, known to military men, was the Nebelwerfer 41 which means Fog (or Smoke) Thrower Model 1941. The Russians referred to it as a six barreled rocket mortar which is a good descriptive term.

The Nebelwerfer is mounted on a somewhat modified carriage of the German 37 mm. antitank gun and consists of six thin-walled launching tubes, 150 mm. in diameter and open at both ends. The six tubes are mounted around a central shaft in such a way that they can be spun around it and that the whole assembly can be elevated as a unit. A fingerlike projection at the rear end of the launching tubes prevents the rocket shells from sliding out backwards when the tubes are elevated. Inside the launching tubes there are three straight guide rails about $\frac{1}{3}$ of an inch deep.

The rocket projectiles, according to Russian sources, weigh 25 kilograms (about 55 lbs.) before firing. They are ignited electrically, the fastest rate of fire observed was the discharge of all six tubes in as many seconds. Full range seems to be around 6000 yards, the flight of the projectiles is fairly steady, the accuracy is also fair, although far inferior to artillery fire under similar conditions, as can be expected from projectiles with steadily shifting center of gravity.

While the name Nebelwerfer indicates that the weapon was primarily developed as a chemical mortar for the laying of smoke screens, most of the shells used by the Germans at Veliki Luki and at Stalingrad seem to have been of the high explosive variety.

And just as the name Smoke Thrower is not quite correct, the designation 41 seems to be misleading too. The weapon may have been adopted in 1941 but it is much older. In fact it seems to go back in a straight line to the "aerial torpedoes" (Lufttorpedos) advocated by the Swedish Baron von Unge during the first decade of this century.

R. H. O.

The Diet of Chinese Soldiers and College Students in Wartime.—T. SHEN of Tsinghua University, Kunming, China, gives some very interesting data on this subject in *Science*, Vol. 98, No. 2544. Based upon 1,178 rations issued in 124 messes in South China in the spring of 1940 and the food consumption data of 11,338 soldiers for a month, a base ration has been formulated. It consists of 953 grams of rice, 274 grams of leafy vegetables, 10 grams of fat and 13 grams of salt.

The ration provides probably enough calories for an adult having physical work, enough protein, nearly all from rice, and a very small amount of fat, which furnishes less than 3 per cent of the total calories of the diet. It supplies

sufficient iron, barely enough calcium and too much phosphorus from rice, thus with Ca : P wider than 1 : 4. In regard to vitamins, it is worthy of note that practically only from the 274 grams of leafy vegetables the soldier gets his vitamin A in the form of carotene and vitamin C; and from the rice bran left on the low-grade rice he gets his antiberiberi vitamin. The actual vitamin intake cannot be estimated correctly because of the lack of analytical data and loss of vitamins through cooking.

The efficacy of this ration has been reflected on the nutritional state of soldiers based upon the measurements of 3298 of them. Their height-weight relationship is just about normal for the average southern Chinese. According to medical examinations of the soldiers, the incidences of vitamin B deficiency are higher in those groups where polished rice is used or the rice water is wasted. It has been found that new recruits usually have a poorer nutritional state than seasoned soldiers, the explanation of which cannot be based only upon diets.

In regard to the diet of college students (man) in Kunming, a dietary record of 160 students for two months during different seasons shows that more varieties of food are listed. An average ration consists of 423 grams of rice, 125 grams of leafy vegetables and tomato, 48 grams of tubers and roots, 68 grams of meat and eggs. It is a better diet than the soldiers' in respect to protein and fat, but still low in minerals and probably in vitamins too. About 50 per cent of the students tested can be grouped as sub-clinical cases of vitamin C deficiency.

This nutritional study of the students leads to the supposition that the vitamin C nutrition of Chinese soldiers may be unsatisfactory too. One thing of special interest, almost no sugar is allowed the Chinese soldiers, and little is consumed.

R. H. O.

New Multiwall Paper Bags Protect Products in Outdoor Storage.—RICHARD W. LAHEY in *Chemical and Engineering News*, Vol. 21, No. 18, states that in order to meet the needs of the Quartermaster Corps, the Bemis Bro. Bag Co. and the American Cyanamid and Chemical Corp. have jointly developed a new type of multiwall paper shipping sack which protects its contents when stored out doors and can withstand transportation and handling abuses while soaking wet. This work required a period of 8 months, the last of which was used to demonstrate the worth of these containers by actual tests.

These bags differ from ordinary multiwall sacks in two important respects. In the first place, flannel-lined cotton tape is used to replace the ordinary creped kraft tape at both the top and bottom closures. This tape is held in place by regular machine sewing through the tape as well as all walls of the bag. Each bag end is dipped in amorphous wax to provide waterproofing at the stitching. The cloth with flannel lining acts as a wick and draws the wax into the inside ply and it actually forms an effective barrier for the whole length of the stitching lines. It therefore is protected against scuffing, etc. Bags protected with ordinary paper tape when dipped in wax tend to form a coating on the outside of the tape. This waterproof barrier is therefore liable to be destroyed with handling and scuffing which occurs in transportation.

The second important difference in these bags is that they are fabricated from paper which has been treated with melamine resin to provide high wet strength and resistance to scuffing when wet. This resin treatment actually gives the wet paper 30 to 40 per cent. of its original dry strength. Asphalt-laminated wet strength paper has been found to be much superior to the plain paper laminated sheet. The reason for this is that the ordinary paper has a tending to disintegrate when the outside surface of the laminated sheet comes in contact with water. Likewise, when water penetrates through an imperfection or pinhole in an asphalt-laminated sheet, both plain paper faces of the sheet soften at the point of entry and gradually the hole is enlarged. The melamine-treated sheets will resist this increase in size of the aperture because the paper will not disintegrate.

R. H. O.

New Synthetic Rubber Product.—(*India Rubber World*, Vol. 108, No. 6.) After more than a year of research the Goodyear Tire & Rubber Co., Akron, Ohio, has perfected a method of producing foamed synthetic rubber latex for seat cushions and similar purposes, said to be comparable in most qualities to pre-war Airfoam made with natural rubber latex. The synthetic rubber product is black, however, to identify it from the light gray pre-war Airfoam. The same wide range of densities is possible with both types.

In most cases synthetic rubber Airfoam is much more highly resistant to oil, acids, gasoline, and similar materials than is the natural product. Both types, however, more than meet the R.M.A. qualifications on flex life. Synthetic Airfoam also is generally more resistant to high temperatures over long periods than natural Airfoam, according to extensive tests, and, in addition, will not support combustion.

Natural rubber Airfoam is permitted to seal bomb-bay doors, pilot cabins, and other apertures in warplanes as well as to seal doors and ports of military tanks from rain and sand. It is being used also in the oxygen masks of high-altitude flyers; while it is likewise available for its shock-absorbing qualities to cushion flight and fire control instruments on battleships and warplanes. Other quantities of pre-Pearl Harbor Airfoam, intended originally for mattresses, furniture seats, automobile cushions, etc., are being used for gunwale padding on small U. S. Navy boats which carry personnel and supplies to seaplanes moored off shore. The Airfoam protects the tender shells of the aircraft.

R. H. O.